A

TREATISE ON ACOUSTICS

IN CONNECTION WITH

VENTILATION;

AND

AN ACCOUNT

OF THE

Modern and Ancient Methods of Heating and Ventilation.

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PREFACE.

It appears to me necessary to make a few remarks in advance, as I am anxious the book which I herewith lay before the public, should at least receive a friendly acknowledgment of the many days' and even months' time of my strictest observation. The title of this book embraces much that is of great importance, especially on the subject of acoustics, as the problem introduced in it which I have endeavored to explain and to vindicate, will prove.

It is the first attempt, in its peculiar nature, ever presented to the public ; at least I believe that all the former experience upon the subject of acoustics, referring to public buildings, may be placed in a secondary light, without fear of being considered arrogant. There must be a good cause why this proposed theory has not been advanced by any other higher professional pen previously. And surely the cause is clear, as science in this particular branch is too young, and it is only in this nineteenth century that the nature of sound has been partially discovered. A large field is still

open; many obstructions will have to be cleared away, and many individuals will have to assist, with manifold labor, to concentrate, and confine progressively, the harmonious dictates of nature. I have been often placed in a very unpleasant position, in the construction of public buildings, where acoustics have formed a most important part, and in which the want of knowledge on sound has caused a feeling of actual discouragement to proceed, and I have no doubt many architects have found themselves in the same predicament. This new theory will obviate this uncertainty, as well as confine and regulate sound in its proper course and action, and in being found correct will justify me for the expression of my inmost conviction.

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ACOUSTICS.

Any practical fact relating to science can never be traced, except through the thorough knowledge of nature, and our progress in this sphere will always be either checked or advanced accordingly.

This new and important discovery will undoubtedly prove these assertions, and will produce a plain and striking example, which, I hope, will assist all future arrangements and do away with all the existing evils in public halls or buildings, at least as much so as possible, and the changes will be precisely in proportion to the application of the new remedy to the existing mismanagement of form, proportion, and construction heterogene to nature.

Sound receives its vitality or its life through the air, and, without air sound loses it and becomes extinct.

Before I proceed to explain the new discovery, I will first introduce a number of facts showing the relative attributes of sound in connection with air, from the best authorities, not alone as being interesting, but as a necessity, for the remedy which I propose for buildings of all classes where sound has proved a failure.

" The intensity of sound depends on the density of " the air in which sound is generated, and not on that " of the air in which it is heard. A feeble sound

" becomes instantly louder as soon as the air becomes
" more dense. So you will always find on great eleva-
" tions in the atmosphere the sound sensibly diminished
" in loudness. If two cannon are equally charged and
" one fired at the top of a high mountain and the other
" in a valley, the one fired below in the heavy air may
" be heard above, while the one fired in the higher air
" will not be heard below; owing to its origin, the
" sound generated in the denser air is louder than that
" generated in the rarer. Peals of thunder are unable
" to penetrate the air to a distance commensurate with
" their intensity, on account of the non-homogeneous
" character of the atmosphere which accompanies
" them; from the same cause battles have raged and
" have been lost within a short distance of the reserves
" of the defeated army while they were waiting for the
" sound of artillery to call them to the scene of action."

Science teaches us, that whenever a shock or pressure of any sort is suddenly applied to any material of any nature, whether metal, wood, gas, water, air, etc., it is immediately affected in all its parts, from the point of contact to the whole extent of the material, in displacing and replacing the particles of a determinate volume; and the velocity of the movement of the particles of the mass created by the concussion of shocks or pressure depends solely upon the nature of any material, upon its elasticity and density; sound likewise causes motions with every particle of the air, and as far as the motion reaches, so that each particle with regard to that which lies immediately beyond it, is in

a progress of rarification during return. "All parts which go forward do in their progressive motion strike each obstacle they meet in their way; they are for that reason called pulses, and the sensations which are excited in the mind by the strokes of these pulses on the drum of the ear are called sounds, considered in their physical causes are nothing else than the pulses of the air." "In order therefore to explain the nature of sound I will add the chief properties of these pulses. The first is, that they are propagated from the trembling body all around in a spherical manner. For the pulses go and return according to certain directions from the parts of the body by whose vibrations they are generated; yet for as much as every impression which is made on a fluid is propagated every way throughout the fluid, whatever be the direction wherein it is made in like manner the pulses must spread and dilate so as to form themselves into concentric spherical surfaces, or rather shells, whose common centre is the place of the sounding body. And henee appears the reason why one and the same sound may be heard by several persons, though differently situated with respect to the sounding body."

"A second property of the pulses is that they grow less and less dense as they recede from the sounding body, and in the same proportion with the squares of their distances from the body. For whatever be the force wherewith the sounding body acts on the first spherical shell of air, with the very same force does that shell act upon the second, and that again upon

the third, and so on continually, so that the force which condenses the air in the several shells is given; consequently the condensation which it produces in those shells must be inversely as the resistance it meets with but the resistances are at each shell, and, therefore, since they increase continually in the same proportion with the squares of their distance from the centre, their density must increase in the same manner. By reason of their diminution in the densities of the pulses, those which are further removed from the sounding body make lighter impressions on the drum of the ear than those which are less distant, and hence it is that sounds grow less and less audible, the further they go from the sounding body, and at certain distances become so weak as not to be heard at all."

"A third property of the pulses is, that all of them, whether denser or rarer, move equally swiftly, so as to be carried through equal spaces in equal time. From this property it follows that all sounds, whether they be loud or low, grave or acute, move equally swiftly; the softest whisper making equal speed with the noise of a cannon, or the loudest thunder clap; and it has been found by experiment that sounds move at the rate of 1,142 feet in a second of time, or thereabouts, for the velocity is not precisely the same in all seasons of the year, but is somewhat greater in summer than in winter, on account of the heat, which renders the air more elastic in proportion to its density than it is in the cold winter season."

Any room, hall, church, etc., or any space enclosed

by walls, ceiling and floor, compresses the air in a state of greater density compared with the atmospheric air, and consequently the sound in such places should always be more distinct than the sound in the open air in proportion to a determinate volume, a fact which is of importance and which has been demonstrated sufficiently. Now, if we take even a one-sided view of the case, which represents itself conclusively, this advantage of great density alone would be sufficient to assist sound for any practical purpose, but this is not the case, and why? The density of the air in those rooms is generally in an unhealthy state, heterogeneous to the nature of sound, and even to health itself, from various causes which I will explain more in detail.

It has been mentioned before that the air is strongly affected by cold, heat, dampness, gases, etc., and in proportion as the air varies from the pure state to too much dampness, too much cold, etc., the vitality of the sound is more or less affected. Next follows the mixture of different strata of air, which will each affect the sound more or less in its propelling power, the densities of the strata of air differing; this difference in the state of air is found also in empty rooms.

In halls, churches, theatres, etc., crowded with people, the density of the air increases by the bodies still more; but this increase of density is balanced somewhat by the loss of reflection.

We often find theatres or churches filled with gloomy air before they are occupied; and if the air exhaled by thousands of people assembled be added, it causes a

perfect revolution of different strata of air, even more adverse to the development of intelligible sound. The bad air which is created by exhalation is heavier than all the rest, except atmospheric air, and naturally sinks to the lower portion of the hall and diffuses itself, the more so where there are galleries; and precisely in proportion as this bad air increases in volume the sound becomes less and less, in a theatre it being noticeable first in the pit, then in the first gallery, and so on upwards; and hence you will often notice that in the upper galleries, or upper parts of the house the hearing is more distinct. Bad air, it is true, becomes much more dense, but the substances of this air are poison to the vitality of the sound, as well as to health, mind, lungs, and voice, and this proves that sound can only carry out its function when well supplied with healthy and congenial air. If you notice the changes of sound in crowded houses, and follow its diminishing state of existence, you will first find its nature often in tolerably good humor, then it becomes delirious, and is placed in a most uncomfortable position, not knowing which way to turn; poison on all sides, ever anxious to do its duty, full of its natural vitality, it becomes disheartened, leaves first its battle field, the pit, next the first gallery, then the second, third, etc., and at last, exhausted, looks up as high as possible to gain rest in the strata of warmer and more flexible air, air more congenial to its nature, which is always found at the highest point.

This is a true picture of the condition of sound in

theatres, etc., where there is not a proper ventilation; and why has ventilation not been applied for this purpose of propagating sound? Because ventilation is comparatively new, and is hardly, or very little understood in its proper light; in its effect upon sound in buildings no such idea has as yet become known, and it is strange, but nevertheless true, that there cannot be found a book on acoustics, that I am aware of, in which ventilation is mentioned in connection with it. Ventilation here forms the most important part in the consistency of nature, and if only properly and scientifically executed, the greatest point is gained; form, however, and construction, proportion, and size, materials, and even art has to be introduced to form a combination or amalgamation to gain success, and to be truthful to the dictates of nature, which never deceives.

Architects hitherto have considered form and material and size the only prominent features to assist sound, and hence the uncertainty of the results. The prevailing opinion is also established, that vaulted and curved roofs and ceilings act as mirrors upon sound. In one of the cathedrals in Sicily the Confessional was so placed that the whispers of the penitents were reflected by the curved roof, and brought to a focus at a distant part of the edifice. There is also a whispering gallery in St. Paul's Cathedral in London, a most astounding phenomenon, a mere accident not calculated upon originally. Now, if we rest upon the assumption that a pure air, genial to sound, guides the

path of sound, this mystery is solved at once. I will here explain how such a singular case may be effected. The St. Paul's Cathedral, in London, and the Cathedral in Sicily are large edifices, with exterior as well as interior walls of solid masonry; they are only used on particular occasions, and ventilation is entirely foreign to them, and the consequence is that the air in them is almost like cellar air, damp and heavy, inclined to stop the pulses created by sound, in consequence of which the lower strata of air are repulsive to sound. All the warmer and more elastic air at the highest point in such buildings is always created by a draft of air from doors and windows, and somewhat vitalized by the sun reflecting its warmth through the windows, no matter what the colors of the glass may be; although some colors have the tendency to draw heat more than others. The air introduced into these buildings by draft from the outer atmosphere is often lighter and of better quality than the inner air, and rises according to its flexibility to the higher places under the ceiling, and a somewhat continued draft will certainly have the tendency to clarify the interior air of a dome, for instance, like that of St. Paul's Cathedral, and it will always be a focus of attraction, especially where there is much light introduced, even without escape of air. Now let us trace our steps to the Confessional, and follow the voice from the pastor's lips, and his position.

The pastor is situated in the Confessional, a box or tube in form. In this tube the air is more dense than the surrounding air, and it gains more vigor, the

pastor's head being about 5 feet or sometimes more above the level of the church floor, his voice strikes above the lower strata of damp air, which are the heaviest; and, as the strata become lighter and more elastic according to their elevation, it is natural that the sound rises immediately to the higher strata and continues under the ceiling to a certain distance, till it strikes a volume of air which has been revolutionized by draft from the outside or to a locality where those influences are mostly concentrated, and hence the downward movement of the sound to the lower part of the building and to a distinct place; in fact the sound marches swiftly beyond the heavy volumes of air contained in the body of the church, and seeks a path downwards as soon as nature assists. Now, some might take it for granted that this same effect might be gained by placing the Confessional in another situation, and it would likely prove a failure; but this would be no criterion, no proof whatever, against the theory advanced, because light may be more effective on one side than on the other, the draft of air also may be more on one side than on the other; much also will depend on the situation of the building itself.

The theory advanced will also abolish sound-boards over pulpits; how is it possible that a sound-board, even 8 or 10 feet square or circular, should cause the sound to descend to the lower strata of air full of poison; never will its nature consent to such unreasonable demands; no, it will, like a bird leaving its open cage to seek its liberty, pass the outlines of the sound-

ing-board to rise to a higher sphere, in the very reverse direction to that desired. Forget not that sound is of a nobler character than generally supposed; its requirements are a distinguished treatment, and it will resist every infringement upon its dignity, and hence, not only through science, but even art, is an approach for hearing possible.

In my own experience at several of the public buildings in this city which were erected under my superintendence, for example the old Academy of Music in Fourteenth street, a building of more capacity than any of modern times, sound proved to be excellent. In another public building, where the ventilating apparatus was, in the hurry of opening the building for the first night, neglected, in fact entirely forgotten, all the ingress and egress of air was hermetically closed; the house was crowded to excess, and the heat and bad air accumulated so much that the sound became perfectly unintelligible. I noticed the effect, and in half an hour after the apparatus was in action, the sound became perfectly clear and distinct.

Many illustrations and examples to prove the bad state of air existing in most of our public buildings might be introduced, and its effect upon sound, but I think it better to pass over them; however, I will take the liberty of saying a few words, and will point out the causes why the Hall of Representatives and the Senate Chamber in the Capitol at Washington are anything but desirable for the purpose of good hearing. Each of these halls is of an oblong form, the galleries

project from the enclosing walls inwardly on all sides, and are of considerable depth enclosed underneath. Each hall has a large skylight corresponding with the form of the hall; in such the light is not direct, but only a reflected light, and in gloomy days hardly sufficient, rather dull; the Speaker's desk is placed on the longitudinal side of the hall, and the lower seats radiating in a circle towards the Speaker's desk. In the lower part of the halls enclosed by the galleries, the contracted space naturally assists sound, the air being more condensed; but ventilation is insufficient, and the lower columns of air being heavy, the sound rises above the galleries to the more open space above. If the two halls were calculated to be occupied for only a few hours' time, and well ventilated, it might answer very well; but being occupied the whole day and often crowded, the quantity of air contained in the whole space is insufficient, and as the ceilings are too low above the galleries, the strata of air become very offensive, and with the dim light through the skylights you will find those halls anything but pleasant; that the elastic vitality requisite to clear reflection of mind and sound is impaired, and that the bodies become feverish, nervous and restless, none of the Senators and Congressmen will deny. The exclusion of a direct light, which always gives life and elasticity to a congenial air for sound and health, aside from the effect of a poisoned air, was a great mistake. If these halls were better ventilated, with the light as it is, they would be excellent for fattening purposes, but ruin to the liver.

In regard to the form of these halls, I will refer hereafter. Strong lighted halls will always be best for sound, as light is part of ventilation and adds great elasticity to the air.

The sun, our great benefactor, supplies us with heat and light; the whole day long we enjoy this blessing direct, and through this influence the night air remains healthy. Now imagine a locality like the Senate Chamber and Hall of Representatives, insufficient in ventilation, insufficient in the quantity of air, and in the exclusion all day of direct light; could the result be expected otherwise? I will introduce here another example to prove the correctness of my assertions. You will sometimes find theatres, churches, etc., with tolerably intelligible sound without much ventilation, and how is this possible? Then mark, in all those cases you will find more air than is requisite for breathing, and consequently it takes longer time to affect the air with poison, or the house is only partly filled, a circumstance which assists much; but to assist sound by increasing the volume of air more than necessary would be an expensive operation, and then it would only be one-sided, and would to a certain extent put a restriction upon the use of the house.

This theory will lead to innumerable changes if properly followed; it will infuse fresh air into the lungs, and add to health; it will arouse the stupor of the audience, caused by poisoned air; it will assist eloquence and strength of voice; it will assist sound reasoning, and it will assist to elevate the mind. Will

not this theory benefit multitudes of hearers who now, in thousands of cases, go home dissatisfied with the loss not only of their time, but, with it, the loss of knowledge, as it was impossible to hear, and the opportunity for gaining which may never return? A stamp will be placed upon future temples of a true character, which will allow thousands of people to assemble, and afford a more extensive diffusion of knowledge, the want of which now is so keenly felt.

SIZE AND FORM OF PUBLIC HALLS.

Now I will turn to the details of size, form, materials, and art, to show how necessary these attributes are to assist sound, even in all its full vigor of life. Sound must have no obstacles; its nature is disturbed almost like the sharp edge of a razor; no matter how perfect the steel may be its nature is the same, that of the most refined kind, the most susceptible of any inharmonious infringement.

No doubt every reader will admit that a certain extent of space is necessary for the diffusion of sound; if the space is too large the sound will exhaust itself at a certain distance; this fact proves itself almost daily. Many experiments prove that in theatres the sound from a clear speaking voice is distinctly heard to a distance of 80 feet in front; but this is a maximum not to be overstepped; in the direction of 60 feet on each side, and in the rear, of 40 or 50 feet. This proportion of figures will lead at once to the conclusion that the

best form for sound or distinct hearing will confine itself to the circle or egg-lines ; the extent, however, of distinct sound in buildings, other than theatres, where the arrangements of seats and form are different, may even reach the distance of 150 feet in front, on each side 80 feet, and 60 feet towards the rear, and even more. The first named figures, as I stated before, led to a circle with the central point 20 feet from the speaker, or to a form approaching an ellipsis.

The three-quarter circle form has proved itself the best so far in a theatre ; but still improvements might be made even in this form. The three-quarter circle lines near the ends are not calculated to contract the sound in its forward march sufficiently, and a funnel-like direction of the side lines, starting from the proscenium in an oblique direction to the right and left, inclosing the lines with a circle, would surely assist the force of sound in its forward course ; this arrangement would allow many additional seats, would not only assist decoration, but even construction and save expense. Without doubt the best and most practical method to strengthen sound in any building calculated for hearing, is to break the same in such a manner as to facilitate its natural course from its original starting-point toward the hearers, with due regard to the natural and reflecting or broken sound, producing differences in time, which would lead to confusion rather than strength, and to avoid this evil all walls or objects calculated to confine or break sound should not be too far distant from the place of the speaker.

The form of the ancient theatres, the semicircular form, has been found altogether impractical for modern stage arrangements, and insufficient for a large number of seats, the most important demand of the present day. The forms of the newer times which have been recommended and which have been executed are the following:

1. An oblong, closing with a semicircle at the end.
2. The semi-elliptical form.
3. A part of a circle larger than one-half, or semicircle.

All these halls may have galleries, one above the other in similar outside lines, and should in all cases, except in very small buildings, descend towards the proscenium. In the old Academy of Music, the galleries descended 8 feet from the middle opposite the stage towards the proscenium. This mode of construction allows better sight, and more seats are gained; another advantage is, the sound reaches directly to every spot without interruption, and it gives an increased perspective effect, which adds to the splendor of the building, and, in fact, transforms a theatre to a most cosy place. This arrangement should never be neglected, especially for opera houses, where most of the visitors desire to be seen in their costly attires, as well as to see. In planning the old Academy of Music I was forced to this arrangement, viz.: the descent of the galleries, as the number of seats required was 5,500, and without it many hundreds of seats would

have been useless. This immense descent of 8 feet, never known or executed in any other theatre before, was one of the main causes of the success of acoustics in that house; the great number of seats in the galleries, seven and eight rows in depth on the side alone, demanded a great height of the building; 78 feet was the height from the middle of parquet floor to the ceiling, and this space gave such a volume of condensed air that, without ventilation even, it would have secured at least for two hours' time a healthy and congenial air for sound; but here I will add that all the walls, ceilings, gallery-breastworks, etc., throughout the house were covered with boards tongued and grooved so that every part formed a sound-board. The shape of the auditorium ceiling formed part of a circle, its centre point about 4 feet below the parquet floor; this form is necessary to prevent the rays of sound from concentrating more toward the middle of the building than toward the side walls. The outlines of the auditorium of the old Academy approached more the shape of a funnel with a semicircle at the end; the proportion of the auditorium was beyond any approach to known forms, the depth being about one-third more than the width; a deep proscenium suggested itself to lessen the proportion, and this very depth of the proscenium proved most excellent for propelling sound, as the air in the direct neighborhood of the originating point of sound became more dense, besides allowing a decoration so befitting for the frame which incased a living and most attractive picture.

I will, however, return again to the forms of theatres in use before mentioned. The oblong form, with a closing semicircle at the end, has many advantages; it allows a plain construction and many seats, and in it the sound is clear from obstructions, and its action is clear and natural, but good sight could only be gained by terracing the seats towards the proscenium, which would be unpractical for proper decoration, and would leave many seats near the proscenium useless. Three theatres only in Europe have come under my observation; one in France, one in London, and one at Mannheim in Germany. To retain somewhat the advantages of the oblong form, the elliptical was substituted, with a partial success; better seats near the proscenium were gained in comparison with the oblong. Dumont and Langhouse have written on this subject, and especially Mr. Langhouse, the architect of the Berlin Opera House, in his work considers the elliptical form as the best; he sets forth many advantages: "He says there is no echo possible, and all the circular or rotatory movements vanish." (Echoes are only dangerous in very large spaces; but more on this subject hereafter.)

He states further: "If the speaker places himself on one of the centre points, or nearly so, the rays of sound reflect only once, and unite in concentrating at the other centre points without causing any confusion."

"Stüler," the great Prussian architect, sets forth his objections to this form, and says:

1. "The distance of the hearers from the point of the speaker differs so much that an unequal arrival of the sound rays is the consequence."

2. "The rays of sound will not be likely ever to be forwarded from one of the centres to concentrate and unite at the other centres all at the same time; on the contrary, many concentrating intermixing rotary movements will be produced, and he points out, that, after all, the concentrating points for the rays are at the middle, and adds, that in this very locality confusion takes place, or at least where the harmonious fulness of sound is lost, and gives as an example the Opera House in Berlin."

To avoid all those difficulties, parts of the circular form were substituted till they reach the three-quarter circle.

As I stated before, the semicircle, aside from the disadvantage of not allowing many seats, prevents a good connection with the proscenium.

The circular or rotary movements, which take place in a full circle, are in a three-quarter circle somewhat avoided, the proscenium placing a barrier in its way; and here it is to be added, that a large number of sound rays will extend to the stage and lose their strength by striking the flats which do not reflect, and no resounding or echo is possible; the partitions also in the galleries for the divisions of private boxes hinder the rotary movements. It is true there are even in the three-quarter circle rotatory movements, but they do not amount to any serious obstacle. The views of

architects generally to remedy the evils of the before mentioned forms were manifold. I will here state a few more, merely for the sake of example and for the purpose of proving that after all these experiments, which were very good and laudable in themselves, the results were one-sided only. One of the many methods to assist sound was, to construct flues with openings, on the principal galleries opposite the stage, extending above the roofs like chimney flues to create a draft, but this proved a failure; too much draft in those flues inconvenienced the hearers, and as the forward movement of sound is much swifter than the draft in the flues, the desired effect was lost. Another proposition was introduced to assist sound, and to prevent the rotary movement by constructing semicircular projections like bay windows, in front of every private box, and this is reported to have done some good; another proposed method is, to cover all the boxes with drapery, which deadens the sound completely, an evil worse than the one to be superseded. A great evil caused by the construction of galleries, should be mentioned and noticed; here, in some American theatres, the galleries are very deep, in order to allow many rows of seats; the projections of those galleries opposite the stage are often so large that they almost reach the middle of the auditorium, and the height from the floor to the lower front line of gallery breastwork or railing is seldom more than ten feet, with a ceiling underneath running parallel with the rows of seats somewhat shed-fashion; this construction not only prevents the sound

from entering direct, but gives under the galleries a most uncongenial place for sight and comfort.

Perhaps a retrospective view of all the arrangements and evils connected with them, to gain intelligible sound, especially in theatres, here finds its proper place, and I will therefore proceed to explain why all of them have only partially succeeded. I say partially, because the results refer only to form, size, and materials employed, although combined they were intended to promote good sound, and that failed. The experiments individualized the attributes of sound only, but the individuality of sound itself, its living vitality, its food, its digestive nature, was insultingly neglected, and its perplexing, stubborn, and resisting power was plainly visible, and so sound became a subject looked upon as very fickle, unreliable, expensive, and even dangerous to be dealt with, and fell into oblivion; but this *status quo* cannot last, this is sure! so let us take it up again and try if we cannot push it forward, out of its stupor to its proper light, and instal it into that high sphere to which it belongs, and where it can shine as one of those millions of examples of God's wisdom in his beautiful and harmonious dictates of nature, which are all to our benefit and blessing.

The human body, the lungs, etc., cannot exist without air, and so the voice, which originates from the body through air, which lives in air, operates in air and loses its vitality without it, should naturally lead us to the conclusion that sound can only be useful in a proper and healthy air, to such an extent as we require;

and it appears that the same influences of impure air acting upon our feeling through our body are precisely the same influences which sound has to encounter. We often hear people say: I have made it a rule not to visit a business man on a rainy day on business of importance, as on such a day his mind is affected; he has not the elasticity of mind to enter into a heavy business transaction; and do you not find on a rainy day that the bells lose their distinct sound, and even the rattling of carriages and carts passing in the streets is of less noise? don't you feel gloomy yourself on all such days, and restless? do you not notice what a difference presents itself when you rise early in the morning and inhale a clear, fresh air, which gives you an elasticity mentally and physically? Ask the musician whether he does not notice a change in tone by such influences in the atmosphere; ask men of science who make sound their special interest and digest over it, and examine its characteristics still more exhaustively, and you will come to the same theory which I have introduced, based upon my own past experience and assisted by inductive reasoning between known facts and phenomena and the laws or principles which govern them.

The number of illustrations I introduced at the beginning showed the effects of the atmosphere upon sound, but keep in mind that the atmosphere which surrounds us in public buildings differs from the combined atmosphere of that grand space between heaven and earth; this mistake has misled many architects in

their constructions, and to most ruinous results; yes, I know of one large church, costing one million and a half dollars, which proved to be entirely unfit for use, and remains so up to this time. In this case the architect took it for granted that a cannon fired in a valley could not be heard on a high mountain, and *vice versa*, and he built a large cupola of great height, forming the main body of the church, supposing that the sound would not rise over 60 feet above the floor, a rule often introduced, but not applicable to the atmosphere contained inside of buildings, and therefore took it for granted that the cupola above the 60 feet could not be reached, and prevent the forward march of the sound; but the very reverse result was noticed. With no ventilation to regulate the different strata of air, the sound rushed up to the cupola in force, finding the lower strata of air heavy, causing a rotary circular movement of the rays, and, partially returning in a state of confusion, became wholly unintelligible.

The atmosphere in public buildings cannot be the same as the outer combined atmosphere. Why, the very fact that we are living in the lower strata of the atmosphere proves it, and hence it follows that we have in our buildings the lower strata of air in whatever condition we find them, in their natural state, but condensed; we often find them damp, heavy, cold, and, with too little ventilation, overheated. In public buildings we have only one atmosphere to battle with, for our purpose a very lucky circumstance. Only imag-

ine, if the inner atmosphere in a building were exposed as much as the outer, the sound would be very often in the most intense state of excitement, and it would be impossible to arrive at means to prevent it. See how thoroughly that immense space between heaven and earth filled with air is ventilated; to go into details and to understand them perfectly, would require the knowledge or theory of the wind, the evaporation process of the earth to produce clouds in order to replenish the earth for the loss sustained by the sun, etc.; look at the daily changes of temperature, yes even hourly, the different seasons of the year, what does all this mean? Why, ventilation, to give a healthy inhaling air to the living, and by the living I mean all objects we see, that are full of life.

Now let us see what we have done with this single stratum of air, a distinct atmosphere which is left for our buildings; why, we have done almost nothing, we have not supplied it with sufficient fresh air, we have not regulated the different strata of air, we have not stopped the influence of the poison produced by the exhaled air, and left it often to the tender mercy of materials, which become dangerous by the neglect of this impure state, and these neglects have to be avoided, or we can not succeed. Nature has helped us much, she has given us a condensed atmosphere entirely clear of outside influences, and this alone should be an inducement to relieve the evils mentioned, to prevent that cankerous odor of a stagnant atmosphere. Let us trace now how an impure air operates on the reflec-

tion of sound, and how all those movements so dangerous to intelligible sound have been produced.

In almost all cases in the present state of the atmosphere in our public buildings without proper ventilation, the reflection of sound becomes confused by obstructions and angular forms in its march; but the main cause of this annoying result originates more in the different strata of air, part of them being saturated with matter which is heterogene to the distribution of sound throughout, and which confines the sound to certain strata only; and as the heterogene strata always form their layers at the lower part of the atmosphere, saturated by the exhaled air, and of a greater specific weight than the others, a distinct division of the upper from the lower is formed, and the upper, as likewise the lower strata become condensed. This condensation in one sense should assist sound, and does so in all strata where the greatest purity of air exists, whereas in those strata saturated with impure air, the condensation actually stops the sound, and it becomes unintelligible to a certain degree, and in proportion to the volume of condensed impure air. This proves that the inner atmosphere of a public building under the influence of exhaled air, undergoes two processes of condensation,—the first one by the inclosure of the inner atmosphere cleared of the outer influences, and the second by the exhaled air of the human body, which becomes heavier, and through its weight the second process of condensing the inner air takes place, and this second process of condensation is the most

ruinous process to hinder distinct sound, especially in those places where the sound is most needed. The sound diffuses its rays immediately to all particles of the air, from its originating point of contact, provided the air is congenial ; but the moment the rays find obstructions of a serious nature, they rise to other parts with more propelling power ; gliding over $\frac{1}{3}$, even $\frac{1}{2}$ of the volume of air contained in the building with contempt, and proceeding to the other part, they commence playful and vexatious tricks by rotary movements, by rotary concentrations, by resoundings, etc., and leave the audience in perplexity ; such phenomena you will find in very large buildings, where you would suppose that the rays of sound, deprived of $\frac{1}{2}$ and even of more of the volume of the inner atmosphere, find ample field for action.

Echoes are never found in smaller rooms, but when a sufficient interval exists between a direct and a reflecting sound we hear the latter as an echo. "The reflected sound moves with the same velocity as the direct sound, so that in air of a freezing temperature the echo of a pistol shot from the face of a cliff 1,090 feet distant is heard two seconds after the explosion."

"In large furnished rooms, the reflection of sound sometimes produces very curious effects. Standing, for example, in the gallery of the Bourse, at Paris, you hear the confused vociferation of the excited multitude below. You see all the motions of their lips, as well as of their hands and arms. Yon know they are speaking—often, indeed, with vehemence, but what they say

you know not. The voices mix with their echoes into a chaos of noise out of which no intelligible utterance can emerge. The echoes of a room are materially damped by its furniture."

The presence of an audience may also render intelligible speech possible, where without an audience the definition of a direct voice is destroyed by its echoes.

Sounds are also reflected by the clouds.

"When the sky is clear, the report of a cannon on an open plain is short and sharp, while a cloud is sufficient to produce an echo like the rolling of distant thunder. A feeble echo also occurs when sound passes from one mass of air to another of different density. Thus by day the sound has to pass through an atmosphere which frequently changes its density." Again I introduced a number of observations taken from English and German works, generally known, and find them corresponding in every respect. My intention is to introduce as many examples as possible, so that a more comprehensive view may be gained, especially by those who are less acquainted with this subject. The cause of echoes is here given, but it must be added that the sound will not reflect so intensely to reproduce distinctness unless the form is of a peculiar nature to assist; this you will notice not alone in the outer atmosphere, but also in the inner, or in very large buildings, where the sound rays, owing to their direction of contact in sharp angles, reflect once or twice, causing a resonance, and returning in this condition to the ear. In a Merchants' Exchange, or in

any hall where hundreds of people are assembled, and where each desires his voice to be heard, confusion of sound must take place, as the sound rays sent forward by each individual in different directions, fill the air with them, intermixed, and sometimes to such an extent that it is impossible for a person to hear his own voice. One of these examples is found in the lower part of this city. In such cases it is difficult to remedy the evil altogether, because the atmosphere is overtaxed; it takes the place of a servant who cannot serve two masters, and who recoils quickly at the imposition. But what can be done for a remedy? First ventilate well, then cover the walls with drapery to deaden the sound, especially when the room is not in proper proportion to its height; the third movement is to divide the ceiling by deep sunk panels; if too late, divide the ceiling longitudinally and transversely by sheets of canvas not less than 3 feet in depth from the ceiling, which may be done with colored flags, forming somewhat of a decoration. Ventilation will prevent the accumulation of different masses of condensed air which in themselves would produce echoes, in many cases, the quantity of air not being sufficient for the number of people assembled. In smaller rooms like court-rooms, where only one voice is heard, a deep panelled ceiling would be injurious; if you wish to convince yourself of this, visit the old court-rooms near the New Court House, in the lower part of this city. It was stated before that an audience may also render intelligible speech possible where, without an audience, the

definition of a direct voice is destroyed by its echoes. This is true, and may be accounted for by two distinct causes ; the first is, viz.: by the presence of an audience the sound loses its aptitude to echoes, particularly if the audience is distributed over all parts of the house by galleries. The next cause is : the sound rays are intercepted in their forward movement, and *vice versa* in their return. In public buildings, or localities where the echoes are remarkably distinct, you may rely on it that the construction, the proportions, the form, and size is anything but suitable to the propagation of good and intelligible sound, and this proves the larger the area of an atmosphere the greater calculation and knowledge of sound is required.

It cannot be denied that the use of proper materials in the construction of public buildings forms an important attribute to the propagation of distinct sound, or at least to assist sound. If we examine musical instruments, we find that wood forms the best material ; the thinner the sheets of wood used the more elasticity they gain, and the more susceptible they are to the rays of sound. The sound rays in their forward course through the air are assisted by its elasticity, and the moment they come in contact with the thin sheet of wooden wall they are restrained, but not suddenly or abruptly, as they find still an elasticity to work upon. The sound rays seem to be pleased with the natural, easy, and accommodating restriction; and especially in public buildings, theatres, etc., where the walls and ceilings are inclosed with boards, the sound seems

gratified to be restricted, conscious of its ability to go so far and no farther, to apply its force, and suddenly appear with a round, harmonious, clear and strong tone. But only then is it possible to produce this strength and clearness when there has been no obstruction to the sound rays, and only through ventilation is it possible.

In England several trials have been made with various materials; for example, metal plates were put up to gain a sharp, penetrating tone, especially for speaking purposes, from the absence of elasticity being known; but the result could not be expected to be favorable without the air being first cleared of all obstructions; and even had the sound gained the sharp, penetrating tone, it certainly would not have been desirable any more than that emanating from an empty bowl or hollow pot. Notice the sharp, shrill tone of some of our clergymen in the pulpit, and actors on the stage, how disagreeable it appears, and with the addition of the sharp, trumpet-like tone of a metal plate would it not be shocking? and I am bold to say, the sound rays would become a fearful chaos, and scare the audience to a quick exit. But wood we cannot always use for such a purpose, as the security of the building demands otherwise, and therefore hollow walls, either constructed of stud partitions plastered on both sides, or formed by furring strips on brick or stone walls, will somewhat assist; but it should never be forgotten that materials will only assist, not originate, the desired effect upon sound.

Many theories have been placed before the public ; twenty books on acoustics I had lying before me at the time I was on the point of building the Academy of Music. I felt that without some knowledge of sound I could not succeed ; and here was to be one of the largest theatres ever built; a failure in acoustics was a failure in everything, so for eight days and nights I was engaged in studying those books, and after sifting them all I was placed in the most painful situation ; in fact, the nature of sound was a mystery to me for all practical purposes. In all those books there were not two authors who agreed; the very hobby-horse one rode, another tried to lame, or knocked under all four legs ; all the books proved a perfect mystery of scientific researches. Some of the authors went so far as to prove the rotation and reflection of sound by mathematical calculation, and illustrated them with thousands of lines, and with an infallibility perfectly perplexing; and others, again, had the audacity to contradict its truthfulnes, and still not one of those works had the merit of being generally admitted as correct.

I was not aware that any more books could be found, so my last hope from that quarter vanished, and the only alternative was to fall back upon my own resources. I covered the whole interior auditorium with boards, hoping for success—and succeed I did ; but this success was not from the use of wood alone, it was from the immense inner atmosphere and other details which I stated before. Several city papers requested me, after the completion of the building, to publish

the secret of my success for the general good; but how could I at that time, as I knew not how soon my hobby-horse would break down? If my new theory proves correct—and I am convinced it will, although it may at first meet with some doubts—it will raise its head erect in the future when this particular branch of science, ventilation, shall reach its culminating point; then the atmosphere will be better understood, its impurity, its outer influences, its quantity and quality; then a new field will open itself, suggestions will spring into existence never thought of before, and those objects that exist in air, that are influenced by it, and that cannot exist without it, will find their proper attention, but not before! But there is no doubt it will be soon; it is fortunate that ventilation must and will become a subject of great interest; it has already become so; it is necessary for health, the greatest blessing we can have. And why should not ventilation be introduced thoroughly in public buildings? And who can doubt that these sound rays would find themselves at home; would they not playfully enter into every particle of air, and joyfully pay us with a salute of a round, clear, and strong tone, so pleasant to our ears? I am glad to state that the principles of ventilation have taken hold in our country, perhaps generally more so than anywhere else. A new country like ours, with a population full of energy, and minds devoted to progress, cannot fail to take hold of rational ideas to further their interests. Ventilation would have been more extensively introduced, had it not been attempted

in many cases more as a means to make money than for any practical purpose, and it has, in consequence, lost many warm friends, and has been actually an useless expense to hundreds of citizens; in many cases worse than an useless expense—more the means of depriving them of healthy air than if it had been ignored altogether. This abuse, however, will rectify itself gradually. It is very difficult to introduce ventilation into most of our public buildings, especially theatres. I have had several cases where I used my best endeavors to gain good ventilation; in some cases thousands of dollars were expended for the purpose, and what did all my trouble amount to? To nothing. Not an inquiry was made how the ventilation was to be applied. Lessees took charge of the building, ventilation became a laughing-stock to them; moreover, it would have required an intelligent person, with an expense of two or three dollars a night, to take charge and regulate it. But what can be expected from men who become lessees of a building for three or six months, with the determination, if possible, of placing two persons on one seat, without regard to danger of life, comfort, or health? The condition of sound is never thought of—on the contrary, they are pleased for the same audience to re-appear to hear the other half of the sentence. Opposition is not expected, as pretty nearly all theatres are alike, and conducted with similar management. I will not say all, but many of them.

CHURCHES, THEIR FORM, SIZE, MATERIALS, AND VENTILATION IN CONNECTION WITH ACOUSTICS.

It is hardly necessary to point out the forms of smaller churches; no matter what they are, they never affect the sound very materially, unless they become a hot-bed of bad air. The larger churches, which are now in demand, are the subject which I wish to introduce to the readers, a subject which must interest them, as all large churches in this country have proved failures in form and acoustics, to a most lamentable loss to their congregations,—one-half of the congregation cannot hear, and in some cases the inner construction is so arranged, as to lead a person to suppose, that the most necessary points, sight and good hearing, have been studiously avoided, in order to introduce impressions of strength, where actually a very small portion was needed, and this arrangement we may find in churches costing from 600,000 to 700,000 dollars. In one large church in this city where you cannot hear, the proportion or size would answer very well, but want of ventilation separates the aerial volume into two distinct masses, the heavier part below, and the more flexible above; and, in consequence, the sound separates itself from the lower sphere, and rises to the higher, precisely where it is not wanted, and with a strength causing reflecting vibrations of a nature so monotonous as to create a sleepy sensation. There are two classes of large established churches,

namely, the Catholic and the Protestant, and each has its ritual, and has to be treated accordingly.

At the present time the requirements of large churches are, that they be constructed with all possible economy for good sight and hearing, and befitting the house of God, and that as many people as possible may be seated. How far these requirements have been complied with, the many examples rather of a caricature nature give a true synopsis of the actual state of religious feeling of the present day. Every public building ought to be in reality the pulse of the inner life, and the house of God especially should not only be harmonious in its proportions, but of such construction as to stamp it with its true character so impressive to the mind of the beholder.

Harmony, Science, and Art elevate us to a higher sphere of life, and should never be neglected in the house of God.

"Many suppose that the Protestant churches are to be of an entirely different type to and in contrast with Catholic churches; this is a great mistake; the Reformation has not produced a new church—it has only assumed to have abolished the errors and abuses of the Catholic church, and hence a new and specific Protestant style would be a folly. In this field there could be no protest, only an acknowledgment and a necessity for reproduction; and the best style will be the one which has the facility capable of entering into the smallest details of Christian and ecclesiastical spirit in the execution of the whole and in detail, with

a steadfast harmonious consequence, and calculated to represent a most intensive view." The Catholic church presents daily the holy rite of the Lord's Supper, and every person assembled on such occasions should have the privilege of seeing every ceremony in connection with it. The sermons which are preached are short, but from that very shortness they should be heard by every one, and well understood. It follows that a concentration of seats is necessary, with a direct sight of the altar; this is the principal requirement, and how can it be done? The basilica is the oldest Christian form of church, and will, if rightly understood, answer the purpose best. It is the most simple form, less costly in construction, highly favorable for decoration, and its perspective may even be extended to the effect of sublimity, and will admit of almost any style.

It is true, galleries placed longitudinally in the basilica form will not be desirable, and they form in very large Catholic churches a serious obstacle for decoration. Now let us take a space of 65 feet in width and 250 feet in length including the chancel, with transepts forming a cross; the number of seats may reach 2,800, each with a clear unobstructed view of the altar. The next demand is to supply a number of side altars, perfectly independent, with a separate passage. This demand is met by placing the side altars on the longitudinal walls inclosing the side aisles, with 10 feet for the altar, and a passage of 16 or 18 feet in width, say 28 feet in all will form two side aisles in connection with the nave; and their isolation from the

main body of the church will not only assist strength, but will allow a variety of form and of character most suitable to the church. The passage in front of the smallar altars will be a passage likewise to the transverse seats of the main body of the church; large openings communicating with the main body of the church are avoided, and the side walls of the nave are left undisturbed for decoration, and facilitates the concentration of sound. Ample light, also, is indisputably gained by this arrangement.

The front of such an inner arrangement will admit of two towers or one, and an exclusive field for the display of the main front in its proper characteristic feature noticed on all the basilica forms.

Large door and window openings may find sufficient space, also, with an ample portico, etc.; a large church, built on this plan, will at once suggest how extensive a variety of form may be introduced; it will admit even of six towers, with a cupola in the middle of the transept, and an inner and outer decoration may be arrived at, worthy of the house of God.

I will now proceed with the form, acoustics, and size, and prove that the basilica form, or oblong form, is much better calculated to assist sound than any other.

A space 60 by 250, arched or covered with a horizontal ceiling, forms in itself a tube with a condensed volume of air, having the tendency to restrain the sound from spreading sideways, and to guide it in a forward direction similar to a pipe or tube, which we all know throws the sound to an almost incredible

distance. Notwithstanding this space is of large size, the influence, nevertheless, is the same.

The fact is proved that the voice in large spaces may be heard 150 feet towards the front of the speaker, 80 feet towards each side, and 60 feet to the rear; this is, however, the extreme extent under very favorable circumstances. This simple example shows how important form is in large churches to assist sound, and requires no further comment.

Gothic arches have been considered an obstruction to sound, not only owing to their main elevating outline, but more on account of their deeply recessed forms, which naturally create points for reflection in badly ventilated churches; but large columns are the most objectionable parts of the church; they not only obstruct sight, but give successive points for the reflection of sound, and should be avoided in all cases.

In the upper part of this city you will find a church in oblong form with a pointed roof, where you cannot hear; this case seems to prove a contradiction, but by closer examination it is nothing but a natural consequence. The roof is put up in a very sharp degree, and rests on a wall not very high from the floor; in fact this construction deprives the actual aerial space requisite for good hearing of about one-half of its volume. As heat is introduced, the heated air rushes up to the highest point under the roof and there remains, and the sound, in consequence, operates in this very spot so congenial to its nature, and, reflecting from one side of the roof to the other, loses its effect entirely

on the assembled multitude. A sound-board has been introduced, but cannot be of any favorable result. In the beginning I referred to art being necessary to construct buildings for public purposes, and equally so for large aerial spaces. Art teaches us to create proper proportions, and this very æsthetical feeling requisite to do so, should at once put a stop to those low proportioned ceilings which always form an eyesore to the cultivated mind, and especially in a church; good proportioned halls will always prove to be correct and in harmony with the aerial space necessary for good ventilation and hearing; it is strange, but nevertheless true, that nature and science go hand in hand, and to succeed it is absolutely necessary to be perfectly at home with the study of the different branches of science and art.

Church architecture of the middle ages proves the spirit of that age; religious feeling was at its highest point, and was sure to produce the most sublime effects human nature possessed, but nevertheless it has proved to be one-sided, after all; it carried the human souls too far above the sphere of our worldly life, and could not exist for any length of time. We see what art was capable of performing, stimulated by religious feelings; but that time has passed away, and we are now in a sphere of worldly materialism. The present churches prove it; a change is desirable, and would it not be best, at least, to profit by the golden grains left to us, and add practical alterations for good sight and hearing in our future construction of churches

and other buildings, so that the house of worship, as well as the lecture-room, will become more attractive, and assist the advance of human progress ? Let us do away with heavy stone columns, introduce iron columns as sight requires the change, and confine ourselves to those forms best adapted to the purpose, and churches and other buildings will present an attraction of a powerful nature to lead the aspiring individual and penitent sinner to his home. Very large supports or columns in our churches only obstruct the sight and sound, in fact, they are merely introduced for an imposing effect, nothing else, as the ceilings of almost all our churches are constructed of wood and plastered. Iron columns will answer the same purpose as to strength, and are more in keeping with the construction. In some churches in this city where stone piers are introduced, the amount of their cost would have actually been sufficient to construct the entire building fire-proof, with iron and bricks, and the building would have exhibited a greater aerial space and a clearer sight in the interior. Iron construction will eventually step in; although many will protest against it, it is the only construction for our present wants, especially where galleries to any extent are required.

Iron construction in the interior of churches and public buildings is not new ; in secular buildings we use it daily, but in the interior the iron constructions are very seldom modelled to answer a constructive part of decoration, in which there is a large field for improve-

ment. In Prussia iron construction is already introduced in churches and other buildings with artistic skill; and it certainly should not be neglected in this country.

Now we will examine the wants of Protestant churches of smaller and larger size. It will not be without interest to add a few remarks relative to the progress of Protestant churches up to the present time, to prove how large a field there is still open for the future in this particular branch.

"In Prussia and in England this interesting subject has had its due weight, and progress has been made to a certain extent. In Europe, for the past 2½ centuries, the Protestants have been content to use the Catholic churches that fell to their inheritance, and in the erection of new churches they have followed the plan of the Catholic churches, with the introduction of plain galleries, and without any metaphorical decorations." "In England, in Protestant churches, in their inner arrangement, the vigorous zeal to conform to the present demands was first visible." "In Germany (Prussia) "Schinkel," the great architect, was the first who appeared as a reformer in this direction, and a number of his plans show a distinct separation from the main body of the church and the chancel, inclosing the altar service and a distinct Baptistery. Somewhat later this direction was followed up, and two scholars of "Schinkel," two very eminent architects in the Prussian service, were ordered to visit England and other countries, to inform themselves of every new arrange-

ment that might have been made, and after their return they exhibited to the Prussian Government a number of plans of churches for villages and for cities of smaller dimensions; these plans were all adopted by the Prussian Government, and ordered to be published as a standard to be followed in all new constructions of similar demands. The plans of the smallest churches published, in almost all cases represent the oblong form; the body of the church is undivided, galleries are mostly left out, the ceiling always constructed in wood, and the construction itself in every plan is taken up as a motive for decoration and inner life." "The chancel inclosing the altar service, is mostly closed in an apsis form, very seldom in a straight line; the pulpit is placed sideways before the altar, where the chancel comes in contact with the body of the church, and on the side of the altar generally termed by Catholics the evangelical side. The font is placed in the longitudinal axis of the building, below the level of the steps leading to the altar. The exterior is very plain; burnt brick is the prominent material. To harmonize with the material, and to give life and character, the principal forms of the middle ages are predominant; a more picturesque than severe style of characteristic, however, is introduced." This very picturesque stamp would be very desirable for our village churches, and for smaller cities, where the monotony of frame buildings is too frequently visible. It is true, the English in their churches have often made the attempt to create picturesque forms, but each nation seems to have its own peculiar taste.

"That the small Protestant churches in their whole form cannot deviate from the Catholic church or chapel is a natural consequence; only larger dimensions will cause the historical forms of the Catholic church building to come in conflict with the material, and partly, in a certain sense, with the ideal demands of the Protestant churches, and consequently in larger Protestant churches a peculiar varying formation becomes a necessity, and a discriminating character is only then possible, and so the characteristic of large size churches will depend on the form, the manner, and the place allotted to the pulpit and font, and in the arrangement of galleries; besides those positive changes, there are some more negative variations of rather smaller interest."

"The plans published by the Prussian Government for churches of middle size are of the oblong basilica and central square polygon form, somewhat like the Grecian cross. Churches of those named forms are best calculated for Protestant churches; the voice of the clergyman is better heard in them; they admit of deeper galleries, and seat more people."

"The Catholics, however, at this newer time often introduce galleries, and nobody can deny that they are very useful; the opinion of the past eighteen centuries, that churches shall not be constructed for profitable theories, is laid aside and somewhat antiquated. Very large Protestant churches will have to fall back upon the plan of the oblong form with galleries, with a similar arrangement first described for Catholic

churches." The extent of hearing has its limit, and if we require churches of immense capacity we have to fall back on forms which are calculated to assist sound, with good ventilation. The basilica form may be extended to 300 feet in length; but concentrated forms, such as the square, will never answer the purpose for good hearing. A very striking example is one of the churces in the upper part of this city, not very large, but nearly square; the sight is good, but the sound quite unintelligible in many parts of the building. It is not alone that the inside proves how little the form was understood, but more striking by the outside. The form of the church represents a barn with an immense roof. The two towers in front are a mixture of Gothic and Romanesque, the Gothic elevated spirit predominating strongly in contrast with the body of the church, rarely to be seen. In this church we find two elements; the one has special claim to materialism, and the other to an aspiring sphere, a most inharmonious whole, and unfortunately the aspiring spirit is on the outside.

To characterize the interior of the church in front was an impossibility; if it had been insisted on, the barn form would have been still more striking, and therefore the architect felt himself bound to place two elevating towers in front to hide the mistake, and especially in such a prominent situation. True harmony can only be produced, if the inner life is strictly followed in the outer forms; in this case the galleries are secondary, and form no principal divisions in the inte-

rior, consequently the towers are inorganically connected with the body of the church. Square forms of large size, or those nearly square, require an entirely different arrangement, and should never be used for very large churches; aside from acoustics, larger sizes of timbers are necessary, and the decoration has to be rather pretentious, or the building will look empty, and will more or less leave an impression of monotony. "In very large Protestant churches, where galleries have to be introduced, and on a large scale, the oblong form, with nave and two side aisles, becomes a necessity; in such cases it is desirable to add a transept of sufficient projection to allow more concentration. With entrances or outlets on each side, with enclosed passages and stairs leading to galleries extending the main body of the church from front to rear beyond the transept, with one division beyond the transept adjoining the chancel, and allowing the centre division of the transept to be double in size in comparison with the other divisions, and three of the smaller divisions for the body of the church in front, a concentration is gained with two side aisles and nave which will give a grand aerial space, and admit of a large number of seats around the pulpit. The pulpit may be placed on the side of the column at the intersection of the nave and transepts, and a richly decorated chancel; the whole will produce an opulent and rather an unusual arrangement, only noticed in large cathedrals. This will be the form for large Protestant churches, and no other; but we must not forget that there is a certain

extent in size which we cannot overstep." Churches with transepts in connection with side aisles, even with two or more aisles; polygons, no matter of what form of plan, will eventually assist much in the formation of public monuments to comply with all our wants; and the Catholics will, if they do not insist upon retaining large surfaces of walls for other purposes, use similar forms, as they have done already in some cases, and fall back upon the original form of the divided oblong.

"It cannot be doubted that a centralization of form appears to have advantages; but, after all, it will not compare with the oblong form, which concentrates the view to one spot only, viz.: the altar, the most prominent point; and it suggests itself that central forms for churches have not been based upon the requirements of the liturgy; altogether, to produce a majestic and imposing effect, which conforms to the early Christian works of this class, it is not to be wondered that the noble construction of a cupola, in its inner and outer grandeur, and with the charming effect of the upper light in contrast with the more plain form of the basilica, should have been favored. The oblong form, with only one division, will centralize to a greater extent than more; but the construction of monumental buildings in this form becomes expensive owing to its great height in proper proportion, whereas in dividing the width of the building into nave and two side aisles, the height is much diminished in proportion to its width. The idea of building churches and even

theatres to contain from four to five thousand seats with a clear sight and with perfect acoustics, is a mistake, and can only be entertained by architects who are strangers to science. Three thousand five hundred seats placed in one space, with comfort, forms the culminating point of hearing, and any attempt to extend the number of seats further rests on an assumption of knowledge which does not exist. All the reports spread abroad that there are churches and theatres containing five thousand seats, is an error; and if there should be a building of such a class, you may be sure that you cannot hear in all parts of it. Now I will present the reader with facts relating to the minimum extent of aerial cubic feet requisite for good hearing, facts which I gained by many years observations in examining buildings where the acoustics are considered good, and public buildings, theatres, and churches of the largest size which came under my direct care. Churches, halls, lecture-rooms, etc., containing not more than one thousand seats, should not have less than 150 cubic feet aerial measure for each person.

Churches containing 2,000 persons, not less than from 250 to 300 cubic feet aerial for each person, and an increase to from 300 to 500 in proportion to the number of persons; 500 cubic feet aerial will answer for 3,500 persons, even 550 cubic feet aerial will not be out of proportion with a calculation of about 6 square feet to one seat; if more, the aerial space will consume too much sound and will lose its force. Five hundred

cubic feet aerial space will keep an audience pretty comfortable for an hour, as to breathing; but nevertheless, the sound begins to rise after this space of time, and appears distinct for a short period only, emanating from the pulpit about 10 feet above the floor, but loses its strength gradually, and then the lower strata of air become specifically heavier and the sound less audible, and persons occupying the principal seats in the nave naturally suffer the most. A thorough ventilation with proper form to assist sound, willl be absolutely necessary to remedy the difficulty. All the above aerial proportions will, if properly applied, form another link of the consistency of nature, which never deceives.

It may be readily seen that a proper ventilation, consisting of a proportionate supply of fresh air, and a proportionate outlet of bad air, is as necessary as the sound itself, for sound, to be distinctly heard; and hence it follows that churches and theatres with abundance of aerial measure, are often better adapted for hearing than buildings of a smaller size, where the air is impure and has less opportunity to diffuse itself, and the necessity of ventilating smaller public buildings is in one sense of more importance than in larger buildings; this depends, however, solely upon the time of actual use. A church, or a theatre, or a lecture-room occupied for one hour's time, will prove better for hearing than for two hours, and so on; and halls occupied the whole day, like the Senate Chamber and Hall of Representatives in the Capitol at Washington, without

the proper aerial measurement and with insufficient ventilation, prove failures.

In all cases where a public hall is occupied for half a day or more, an increase of aerial measure for each person should be adopted, as the present mode of ventilation cannot be relied on.

The form of our churches which we see daily in this city and in the country, with immense roofs resting on stone walls only 10 feet high, and sometimes divided in the interior into nave and side aisles, with a high tower on one of the corners, is an attempt to elevate the building to a characteristic which it does not deserve, and may be termed an excessive economical measure, regardless of the inner life, placing the elevating spirit on the outside only. And the church committee who protests against such unnatural forms should receive thanks for unerring zeal, if only resting on an intuitive feeling of propriety.

Wooden ceilings and open roofs are often very desirable and have many advantages, but they should never be used except for smaller churches; they will, if properly arranged, allow a very desirable decoration for the interior. The open roof allows more height for the interior of a church, and may be placed on much lighter walls, by which expense is saved; but in many cases the roof forms the most prominent part of the church, and such extremes lead to caricatures of a most striking nature.

There is no cause for fear that the open timber roof diminishes the church-like appearance of the interior,

if the constructive timbers are only properly arranged, and treated with a fine æsthetical feeling, with suitable mouldings, etc., and harmonizing colors, a most beautiful and impressive effect is gained; but in large monumental works the arch has and always will be the most effective form for an impressive and elevating characteristic.

Hitherto it has always been noticed that the ceilings of churches and of other public building have had an important influence upon acoustics; and wooden ceilings and groined arches have proved to be better suited than the semicircular arches, etc.; this is very true, and could not have been otherwise; but groined arches, and even wooden ceilings, as we often see them, have in many cases created bad effects. In one church in Fort Wayne, State of Indiana, constructed with a wooden ceiling, it was impossible to hear, and the confused echoes were actually sent forth from this wooden ceiling. I could mention many examples of the same effect, and why? From the want of ventilation, the force of the sound was concentrated to the ceiling alone, and through its force those very phenomena were visible; and so it will be with any arch, and especially with a cupola, that rises above the level of the church ceiling. The heat will rise to those parts and invite the sound to follow, and it does follow with force, and its general diffusion throughout the church is lost. Now, is it not easy to comprehend that if the air in a church or any other public building is heated equally, and the ventilation good, the

diffusion of sound will be more equal throughout every part, and that the reflection of sound, caused by projections and recesses will be less, especially when the points of contact are at a considerable distance? At this very moment I have received from Berlin an architectural work in which Dr. Dove, a Professor of Science in Berlin, and a very eminent man, gives his views relative to the rules of acoustics, to be observed in the erection of a new dome or cupola in the city of Berlin. His treatise is interesting, and I think a translation into the English language will not be out of place, as I intended to proceed with the same identical subject.

"The problem which has been stipulated upon practical acoustics can be named as the very reverse to that which optics have to solve. All the rays which emanate from an illuminated body shall be concentrated into a point to reproduce the same picture, which on that account could only be discernible at a certain point, whereas the sound rays shall be equally distributed, so that no one individual, placed at a certain point, shall alone hear the orator, but large numbers placed at different points shall hear him equally distinctly. The ages of antiquity have done nothing to assist practical optics, notwithstanding they have done more in single cases than the present age for practical acoustics. The point of view which has guided the architects of the past ages in their construction of temples and theatres appears to be entirely of an empiric nature, and in fact a greater

experience was at their disposal as long as communication was predominating, based upon the living word in its place; writing was very little known, and print altogether unknown. Besides, the recitative may often have been substituted in the place of the common speech, for report says that an orator of the olden time required a musician of the flute to direct the tone of his speech. It may be taken for granted that a thorough theory relating to the propagation of sound rays was entirely out of the question, and particularly at a time when experiments were unknown. It is only in this century that the laws in which sound in its commotion and in its propagating oscillatory motions have been settled, and hence science is too young to fill the chasm left by Antiquity with precise theoretical observations. Tones called forth, directly perceptible at a certain point, can become indistinct when the sound waves, emanating directly from the sounding body agitated at other points, come in contact with each other, or by their self-created reflections from various objects. The surrounding stillness requisite to distinct hearing will obviate the first difficulty; in the second case, which demands here especial attention, there are several species to be discriminated. Since the propagating sound waves are actually produced by their successively following condensations and attenuations in equal distances, and by the intersection of the sound rays at certain points when their paths, crossing in different lengths, happen to meet with the condensa-

tion produced in one case, and with the attenuation in the other. In this case the air will not be condensed or dilated; stillness is produced by the converging sounds of the same height, however oscillatory the motion may be, which increase or decrease the force of the tones, if the respective contrast of the condensation differs in each case whenever the rays cross each other.

We will designate this problem with the name interference. But the deeper the tone the greater the difference between the condensation and attenuation; for instance, by the deepest sound of our organs 16 feet, and by the highest sound of the human voice $\frac{3}{4}$ inch, and in consequence some sounds at a certain height may be destroyed and others become perfectly clear.

The enclosure of great spaces for acoustic purposes, rendered necessary by our climate, naturally increases the stipulated reflections in a manner unknown in the ancient theatres.

By the medium temperature of Berlin (7° R) sound passes through a distance of 1,050 Paris feet in a second, at the freezing point 333 metres. If a reflecting wall is at a distance of 525 feet from the point where the sound emanates, and it strikes directly upon the surface, it will return in a second to the point of emanation. The nearer the wall the quicker the reflection follows the sound, as it is impossible to distinguish more than ten tones in a second if the distance is about 53 feet. The smoother the reflecting surface, the more the reflecting sound increases to

a certain extent. But for the long sound waves the surface which is considered coarse for light is already to be viewed mirror-like. To diminish and control the condition and effect of the reflecting sound rays can be correspondingly acted upon in two ways; first, by changing the surface of the reflecting walls, and secondly, through the form applied to them.

The result in lessening the reflection will be that the irritated tones will operate the same as those produced in an enclosed space. It is evident that the effect in an enclosed space which produces tones depends much upon the points where they are produced or created. In a circular building there are naturally many points which in relation to the reflection of sound compare equally, as all points corresponding to the circumference of a concentric circle comply with this condition. In the centre the echo is stronger because the reflecting rays all of one distance must accumulate in their effect. A most astounding example is the arch of the cupola of the old Museum of Berlin. And likewise is the centre the point from which the words of the speaker are most homogeneously heard if the seats of the audience are arranged concentric, similar to those in an amphitheatre. The theatre in the villa of Hadrian at Tivoli, the circus of Murviodore, the amphitheatre at Nismes, prove this, as all the words uttered in the arena are distinctly heard at all points. The voices of singers, however, become entirely inverse if seated on concentrated seats; the voice unites harmoniously in all parts. For

church music, however there is very seldom such an arrangement. An astounding effect I had an opportunity of noticing in St. Paul's Cathedral in London. Amphitheatre-like seats were erected for three thousand orphans, directly under the dome, and when the singing commenced the effect was sublime. The more remote we are from the centre point the less will be the equal perceptibility on all points of the circle; for, if the sound rays are noticed which spread perpendicularly on the radius of the curve, it is plain to see from a simple plan that on certain points many reflecting rays cross each other, and in other places only a small number, and it follows directly that the perceptibility on various points must be very different. This conforms also to the horizontal section (a well-known example of which is the whispering gallery in St. Paul's Cathedral, London), as well as to the perpendicular section of cupola arches. It is the case here, as in the Palace chapel in Berlin; by placing singers on a continued gallery under the cupola-arched ceiling to perform church music, the music is distinctly heard by every one, whereas the voice of a clergyman placed in a position not high above the altar will produce reflection of sound unintelligible at many points.

The difficulty of the problem to erect churches with good acoustic qualities depends in general on very different conditions, to comply with all of which simultaneously would be impossible.

The spoken words do not require an identical con-

struction of the interior for good hearing with that requisite for a musical piece, if they were even emanating from one point; and this fact prevents conversational pieces being carried out in opera-houses with any success; and from this very cause it is impossible for the voice of a clergyman to fill the space of a dome, originally intended for the execution of grand musical compositions to accompany the mass. In public speaking the strength of sound is much impaired by the walls producing reflections, and hence less distinctness; whereas the walls of the concert-room are often lined with wood, to give a higher and more marked tone. And from this very cause, too, pianos which are for sale are placed on elevated reverberating platforms or floors, as curtains, tapestry, carpets, richly cushioned chairs, will materially weaken the resonance. In St. Paul's Church, in Boston, it is said that the clergyman is only heard at Christmas time, the church being then decorated with drapery. Canon Mills proved perfect in regard to acoustics for the service of the meeting of the Free Church in Scotland, as long as the walls were left unfinished, whereas other buildings with finished walls showed most important acoustic defects. The cause of these different effects of the walls on speech and sound is this, they add force to countless consonants, and a noise is produced which does not appear when clear tones are constantly repeated. A covered space in form of a prolonged square or oblong, has proved to be best for acoustic purposes, provided the tones originate on one of the

smaller sides, and that the place of the originating tones be higher than the space filled with hearers, so that those seated in front may not intercept the tones from those seated behind. In this case the forward moving sound rays are especially directed to the space occupied by the audience. The Berlin Singing Academy proves itself in this respect perfect. Should it be desired to give more distinctness to the words, a half cylinder might be added to the extended square, and with such a curve that the reflecting sound rays from its own walls follow parallel with the more extended sides of the square. With a parabolic curve, the speaker should be situated at the focus of the parabolic transverse section; with a spherical, his standpoint should be at the distance of $\frac{1}{2}$ of the radius from the middle of the surrounding walls. Should the building be arranged for both hearing a speech and a musical piece, a different point would have to be selected for each; for the orator, the end of the building, with the cylindrical curve, and for music (organ and church music) the shorter and straight side of the extended square. These main conditions have been generally introduced into Christian churches, and the basilica of the ancients has been their model.

The main ground form of the basilica forensis was an oblong or extended square, with a semicircular apsis, and an elevated tribune adjoining for counsellors, with a small vestibule enclosing the whole width of the building on the opposite side of the niche. The semicircular extension is about one-half of the

middle part of the whole building, which proved good, practically, and authenticated, by the speaking-tube, that the voice of the speaker is much strengthened, when, from his stand-point, the sound rays are more restrained from spreading sideways. The proportion of the transverse section of the semicircular apsis to the width of the building had the tendency, in the construction of churches, to cause the division of the space by columns, into a nave, with two side aisles. At the place of the Chancellor's seat, in the Basilica Dominica, the Bishop's cathedra, semicircular with his Presbytery, was substituted. But in front of the nave and side aisles a transverse space of larger width was introduced, and, later, the transept, which established the cross form of churches, with the altar in the middle. Then, the Bishop's chair was removed farther to the rear, with an enclosure to confine the lower grade of divines, whereas the nave and side aisles were allotted to the people. On the side of the three main divisions, the altar-house, characteristically marked by the direct adjoining quadratic space, and the transept, with a triple width of the chancel, and the main body of the house, with the nave; the first two were higher than the third. Below them, often a "Krypta" was found, and sometimes, a passing street. The elevation of the chancel is one of the most important arrangements for acoustics, and this arrangement has been essentially retained also in Gothic buildings, only differing in the continued curve being changed to the polygonal. If the transept is further removed from

the chancel, then the ground form changes to that of a perfect cross. By adding to the cylindrical extension the whole diagonal section of all the divisions of the church, then the acoustic requirements are partially assisted; then, also, a passage round the chancel may be arranged so that the chancel may retain its smaller proportions. The grand effect of church music in large spaces is, undoubtedly, enhanced by the right angle form; the broken lines of the arches, the large openings left on the upper parts in the side walls of the nave, and sound openings in the ceiling, are of the greatest importance, especially in very large churches, where a possibly created echo may be removed by being intercepted. On the whole, in reference to symmetrical arrangement upon the longitudinal axis, no intimation is in existence of a demand in such a building to gain a third point acoustically, in comparison with the end point of the longitudinal axis. Where, then, shall the pulpit be, as the sermon forms the centre of gravity of the Protestant worship? It is architecturally so disturbing to the eye, that, in the Basilica in Munich, when not in use, it is always moved aside.

Here are then only two ways open, either not to use it or to preach the sermon from the altar. In a Gothic building of large dimensions the voice will be more distinct if the pulpit is placed in a position where the hearers may have a chance to gather in a large open space.

Without the detailed plans of the new Dome

building about to be erected, I consider it impossible to decide on the most proper place for the pulpit, and especially, as undecided problems cannot admit of solubility; the more so, indeed, if from the beginning no satisfactory solution has been admitted. In general it appears to me, if the original type of our churches is retained, the corner pier will be the best, where the transept connects with the body of the church. The voice enters then into the crossing divisions diagonally, and at this stand-point, moreover, is the freest space. Still more difficult does the problem become if the galleries with a terrace-like arrangement are introduced—for economical purposes. Walls forming divisions must then be avoided.

According to my view, it would be proper to make on the plans certain points at which to place the pulpit without infringing too much upon the architectural effect, and after the building has been sufficiently advanced, to examine the acoustic effect of each, and then to select the best place."

This last named article, written by Dr. Dove, is a very able and distinct synopsis of the past and present state of the known theories, confining the sound rays of speech and musical tones to their limits and effects, up to the present day. All the details given are, no doubt, very precise, and, as generally established, based upon science. Now, my readers, I have introduced this article not alone owing to its great interest and value, but at the same time to form a solid basis to rest upon, and to prove how little reliance can be

placed on a theory of supposed causes and effects which do not actually exist. We all know that there is no certainty of constructing public buildings thus far perfect and distinct for good hearing; and yet clear and distinct speech in a public building is most important. Now, as I stated before, a mere accident led me on to the astounding result, that a clear and healthy air is necessary to restore distinct sound in a public building where not more than twenty minutes previous the air was found in a chaos of mixed impurities.

Dr. Dove bases his experiments upon a medium temperature of 7° R. in Berlin, and gives his results as to the strength and effect of sound rays. This may be all very correct, but has absolutely nothing to do with the effect of sound in public buildings. The Doctor's experiments refer to the actual state of the outer temperature alone, which does not exist in the inside of a building. The inner atmosphere, and the temperature in an occupied and inclosed space, without proper ventilation changes every minute, and the sound rays become irritated to a degree fatal to distinctness. Enough has been said referring to the specific gravity of the different strata of air, to prove how the exhaled air affects the aerial space; and the difficulty is that the sound rays always following the most flexible air, become isolated or distinct in their field of operation, and hence, in this more confined portion of the aerial space, must naturally increase in force, and create resounding effects, and become mixed and

unintelligible. It is perfectly clear that a certain force concentrated in one spot, must have results which will materially differ when the force is distributed; does not daily life prove this assertion?

If the sound rays are spread throughout an aerial space, say in an occupied church, will they act with the same force on the curved ceilings, or even on the larger pillars? Why, the strength of the musical tone is a proof of itself. There is no difficulty for musical tones to be heard more distinctly in any aerial space, owing to their greater force; the force is strong enough to penetrate into all strata of air more or less; but still, even with this propelling force, the tones are often directed to separate parts of the building, influenced in the same manner by the variations of the temperature, and condition of the various strata of air. The example and effects of the variations of speech, and the effect of musical tones, directly under the dome of St. Paul's Cathedral, in London, is introduced by Dr. Dove as a most unmistakable phenomenon; but it must be added, that in this case the difficulty for speech is more than in any other locality, as the dome itself is a condensed tube with an upward direction, carrying the voice with it; and it follows that domes and certain parts of ceilings carried above the general levels, will always have a restraining influence in propagating sound. The effect of the speaker's voice, placed only a few feet above the level of the floor, is lost upon the gathered multitude, and why? First, human bodies deaden the sound, and the heavy strata of

air which always commence to accumulate at the floor, are equally obstructive, and it follows that the floor seats in a theatre or in a church, are the very seats where you hear least distinctly, but the moment the speaker takes a higher situation, say 15 feet or even 10 feet above the level of the floor (this means the level of his head above the floor), the voice becomes more distinct. An arrangement to be recommended in all churches and public buildings.

Now let us take a general view of all the difficulties we have to contend with in our aerial spaces to produce clear sound. In fact, the difficulties are great, and it is only in this century we begin to comprehend how the sound rays move, and on a retrospective view of centuries we cannot be right in confining ourselves to the attributes of sound only, such as size, form, and material, and by substituting external aerial effects for those which exist in the interior of a public building crowded with people, never! We must ignore all those difficulties first, and examine the condition of the inner atmosphere of a crowded house, and then we shall find ourselves in a new field of operation. Who can say that a condensed air mass of all kinds of impurities will not affect the sound rays more or less in its force to penetrate? Let us hold on to all the forms, size, and materials which have the tendency to assist sound in its progress and effects, and furnish a pure air through ventilation; then sound will be in its natural element, and perform its duty. The perfect chaos of theories introduced to assist sound have so

far in one sense actually been detrimental to any advance in this branch of science; a perfectly repelling influence has been the consequence; and how could it be otherwise, with so many theories presented?

Now, the next question will be, how can we procure a pure and healthy air in our public buildings? In an auditorium occupied with people, say two hundred persons, allow four cubic feet of fresh air per minute for each individual, also the total amount per second $\frac{200\times4}{60} = 13\frac{1}{3}$ cubic feet. It must not be neglected that the capacity of the flues for escape of impure air should be at least one-fourth larger than the supplying flues.

In concluding this subject, I will here add, that this new discovery to gain intelligible sound through ventilation, settles this fact, that sound depends principally upon a clear and pure air for intelligible hearing, and is not dependent on the attributes of form and materials altogether. But the moment we imprison or inclose the sound, the sound becomes immediately restrained by form and materials in its natural action, and proper form and materials become a necessity to guide the sound rays to their proper channel and extent, with proper clearness. And as this application has not been sufficiently attended to, failure has been the result.

GENERAL VIEWS OF HEATING AND VENTILATION.

Ventilation has not yet arrived at perfection to a point of mathematical precision; but this, although desirable, is not absolutely necessary. Heating and ventilation are branches of science which have received thus far, a general acknowledgment, embodying principles of the greatest importance; but the application of those principles for practical purposes has proved insufficient. How pressing this deficiency has been felt, is proved by the various experiments introduced, even on the largest scale; thousands of dollars have been expended to gain the point of a healthy circulation of air, in some cases with more, in others with less success.

Now, let us trace, from those many experiments, and their failures, the truth of the above assertions. All the appliances, either natural or artificial, to gain a healthy circulation of air have proved insufficient, and this fact leads to another important one, that the atmosphere with direct and indirect influences has not been properly understood, or else the appliances would have been different.

What fault can we find with the present systems of ventilation and heating? Why, the fault is this: Public buildings have been only partially ventilated and heated, and the air contained in them revolutionized more or less, without regard to the natural consequences arising from such arrangements. What

constitutes a perfect ventilation? Nothing more than a moderate and equal temperature throughout every part of the building, consisting of a fresh and healthy air in a continued flow of supply and proportionate escape without any perceivable motion. The air contained in a building, especially when filled with people, is in a continued state of chemical mixture; yes, the materials of the surrounding walls, ceilings, etc., have their influences likewise, and this chaos of influencing matter is to be removed, or the air cannot be healthy, and those same influences lead sound to its natural grave.

I will here introduce an example given by "Dr. J. Berger," to prove how variously the temperature of air confined in a room heated by a stove is affected, and at the same time give a clear view of the present system of modern heating.

"In a room 20 feet long, 10 feet in width, and 11 feet high is placed a cast iron stove, near one of the corners, immediately opposite a window on the longitudinal side of the room.

"By an outer temperature of 2° R., a thermometer protected against the morning rays of the stove showed the following result:

	At the floor.	At the ceiling.	Loss
1′ distance from window	10°5......	19°......	8°5
At the middle of the room	11°	20°5......	9°5
1′ distance from the stove	12°	23°......	11°

"This proves that the air of the lower part of the

room towards the floor has about half as many degrees R., as the air at the higher parts. You will readily notice the immense loss of actual warm and serviceable air to the inmates. The healthy remedy generally acknowledged to keep the head cold and the feet warm, could not be applied with such a conflicting temperature. On the contrary, the head in its natural position would be warm and the feet cold. This process of heating by the stove, applies more or less to all heating methods now in use, as every one of them leads the warmer air to the ceiling of any room or hall etc., allowing the heat in the downward march to be absorbed by the windows, walls, etc., and scarcely warming the lower cold strata of air where most needed; and in this lower strata is the resting place of the organic impurities caused by the exhaled air, evaporations, etc., producing the actual poison which the lungs detest, and sound abhors. No mode is hitherto known of measuring those mixed quantities of impurities in the air with precision. To come to any near approximation, we must first calculate the amount of carbonic acid contained in the air, and allow that the quantum of the organic impurities are proportional to it. The next point will be to confine the carbonic acid as represented by the most able searchers into the various methods, and with the general result, to prove that the substance and quantity of the carbonic acid is to be found in the upper parts of an inhabited room to a much greater degree than in the lower. The cause is as plain as important. The lower part of the

air becomes warmed through the bodies, and rises with the mixture of impurities, and at a higher point follows the draft to colder parts of the room, and sinks mixed with fresh air, penetrating through the pores and smaller crevices somewhat diluted, to unite again with the organism. If it were possible to stop this downward movement, and carry off this impure air after rising, out of the room, then the carbonic acid substance would never be noticed, no matter how large the assembly of people, or how strong the gaslight might be; but as the impure air will ever repeat its downward movement, so it will repeatedly enter the lungs and affect the system most dangerously." Here is the boundary where words must become deeds; this sickening air must be driven away without mercy, and then we shall have arrived at a point to benefit the human race; health and acoustics will shake hands, and public buildings will become a focus of pleasure and attraction; many valuable lives that adorn the pulpit will be saved from their early graves. How many children who are now prisoners in the unhealthy strata of school air, for a number of years, and return to the new paths of life diseased, will, when all the evils have vanished, return in a healthy and vigorous state to practical life.

Now, we should suppose a speedy remedy could be found to overcome the above-mentioned evils, but let us not be too sanguine; it will not be found for some time to come — not until every person, or at least, a large number of an intelligent class shall become fa-

miliar with this branch of science; then architects and doctors will be forced to fall into line like the soldier into the line of battle, not to destroy, but to rescue valuable life. So it is with art; is it ever acknowledged, without a general knowledge and appreciation? Let us hope that the time will soon come when science will assist and guide us to our duties. It was not my plan at first to enter into the details of ventilation. My intention was, to give a general view only of the present mode of heating and ventilation, and to draw attention to the want of its proper application, so far as in my power, but a few days ago I received a new work on heating and on ventilation, by Dr. J. Berger, written in the German language, which gives many illustrations and suggestions, and with such clearness and adaptation to the purpose, that I thought it best to introduce some of them, with the hope that they may interest the public upon that important branch of science:

"As soon as a stove, placed in a room, begins to throw out heat, so soon the former perfectly calm air will be drawn into a most lively and disturbed movement, and this movement you may readily notice by placing yourself before a window; a sensible cold air draft will meet you, no matter how perfectly the windows are closed; this cold air draft commences whenever the heating begins, and it cannot be denied that it has originated from the interior of the room. Now, to illustrate more clearly this singular movement, let us take the most simple method of tracing it with a small

piece of burning tinder. Hold this burning tinder near the stove, and the smoke will rise on the sides and on the edge of the projecting top cover, but in the middle of the cover it becomes restrained, and, unadjusted, is driven back to the edge of the cover, and from thence it rises again. If you hold the tinder somewhat higher above the top of the cover, then the smoke will partially rise and fall towards the middle.

"These simple experiments give us an insight to the previous examples. It is evident that the air is drawn from around the stove to the stove itself, then becomes heated, and rises upwards in a lively upward current on all sides; but it is equally evident that the heated air above the cover will be dislodged and replaced by the hither flowing cold air. But the colder air can only flow from the direct neighborhood of the stove, and naturally must intercept the flow of air which has been rising on the sides of the walls at different places, often changed and precipitated upon the middle of the cover; it then becomes heated and rises, and, pressed on the upward flowing air, is immediately carried with it in close proximity to the edges of the cover. Further above the cover, where the colder air ceases to supply, only an upper current of air takes place, and the smoke of the tinder above the cover is carried upwards, and its course can be traced to the ceiling of the room. This will occur in a similar manner with larger heated surfaces. If we notice the course of the ascending air, and observe the direction in which the smoke of the burning tinder, placed at various parts of the room

is forced, it is easily perceived that from the upper parts of the stove the main flow is toward the windows and the colder walls of the room, and from thence in a sinking condition again retraces its steps towards the lower parts of air surrounding the stove. By lifting the burning tinder in one part of the room gradually higher, you will notice how the smoke is stronger below; but the higher above, the weaker it is driven towards the stove, till the smoke at last rises perpendicularly; however, it soon changes its course in the reverse direction. On the walls near the stove, where they are somewhat heated, the air does not descend, but rises naturally upwards. This illustrated rotary movement bases itself upon the very plainest of fundamental laws. This law is the following: The heavier liquid always falls to the lowest spot. The air cooled by the windows and walls contracts by this influence, and, with an addition to its specific weight, sinks to the floor and presses the warmer air upward, and in such a manner that the higher it is placed, the higher the temperature is marked in the thermometer.

"Near the stove the air receives its progressive movement to the highest temperature. As soon as the air becomes warm, that moment it is pressed by the adjoining cooler air, upwards, and then flows to the more distant parts; and in one place the cooled and specifically heavier air is continually pressed downwards, and at another place, the warmer and lighter air is continually carried upwards, and so the rotary movement takes place consistently with the law of nature. But it

is not to be understood by this that the heated air possesses an inward natural tendency to rise, and that this tendency is really the originating power to cause the movement. This very mistaken idea seems to have been the cause of many errors of the past, and has led to many costly experiments. The greater the difference of temperature between the several air masses, the more energetical, and the more quickly successive the rotary movement will be. It is known that the air in a gassy condition dissolved contains more moisture the higher the temperature, and that the heated air withdraws the moisture from the walls. After the air has been in a considerable degree cooled down, then it is forced to submit to the laws of its moisture, as the cooling process deprives it of the dissolving quality, and so the windows become covered with it. In a room where the moisture is increased by cooking, washing, and by exhaled air, etc., the moisture settles on the cooler parts of the walls, particularly behind beds, wardrobes, etc., and, as the moisture possesses mixtures of other substances, the more it is to be comprehended that, in this condition, ample cause is given for a mouldy and putrefying process. It is an error to open occasionally the door of an adjoining cold bedroom, rarely ever aired; there the moisture begins to form its malignant effect on health. In such rooms fungi are formed, and a whole family, who occupied one of those rooms at night, during a whole winter, were reduced to a most lamentable state of health. The people cannot be warned enough against such

mistakes, particularly from the evil effects not showing themselves directly; they are, on this very account, more dangerous."

MODERN VENTILATION.

All the phenomena referring to this subject may be traced more or less to the movements of water on the principle of communicating pipes. For instance, if two perpendicular pipes are connected by another in a cross direction, and filled with fluid, for example, water, then the water will rise in both of them to an equal height. If different fluids are poured in, then the height of the fluids will be inversed according to their specific weight. If the liquids are quicksilver and water, the quicksilver in one of the pipes will, for example, be one foot, and the water in the other will stand 14 feet high; and it is of no consequence whether the two upright pipes are equal in size or different. If we take it for granted that one pipe is only one foot, but the other 15 feet long, if the latter pipe is continually filled, the water in the short pipe would break forth to the corresponding level of 15 feet, and it certainly would gain this height if its flexibility did not produce a considerable diminution. There are two causes which take the advantage of the flexibility. The one is the weight. This weight draws the rising water parts, the higher they are the most energetically backwards, consequently the upper parts will always rise more slowly, and prevent the lower

from a quick upward movement, and with a pressure causing the parts to shift to a sideward direction. So the water jet spreads out upwards in a conical form, and loses in height whatever it gains in the transverse section. The second cause, the resistance of the air, operates similarly, and this force parts the rays possessed with the natural tendency to the formation of drops, and assists them in innumerable parts to a repeated downward fall. The lighter the rising fluid the less the influence of weight; the influence of resistance however is greater, to which we must bestow our most particular attention. If we place a pipe one foot in length in a high wash-bowl, and fill it with spirits of wine, which is lighter than water, but heavier than air, and let the water rise through the spirits, the resistance would be still greater. We should notice the rising stream easily, and should be able to discern it more distinctly by its coloring the water, and then we should notice that the jet of water upwardly would spread quickly, and by no means rise as high as formerly in the air. If we allow the jet of water to play some time, then the spirits of wine becomes more watery, heavier, the jet wider and lower, till at last, dissolved on the bottom, it becomes immovable. The more compact the middle in proportion to the liquid, which moves in an ascending stream within, the more it spreads, and the nearer to the bottom. All the facts alluded to above will assist and enable us now to a clear conception of the former remarks in our system of ventilation. A very effective and plain ventilation

may be gained at a trifling expense in rooms where no calculation for ventilation has been made. At any point in a room wherever a good connection with the outer atmosphere can be made, place a pipe of tin or of any other material, several feet long, perpendicularly, and inserted in the floor, with elbow at the lower end to connect with the outer air, the pipe or pipes to have both ends open; let their diameter be two or three inches, somewhat in proportion to the room; in a small room only one inch diameter. As soon as the room is heated, no matter in what manner, the outer air enters the pipe, but does not sink into the lower strata of air contained in the room, but rises with increased rapidity in proportion to the increase of heat. If you enter in very cold weather into such a heated room, you will notice a powerful air draft, even at a considerable distance in height, and by placing the hand on the inner opening of the pipe it is pressed upwardly with great force. If we place a short pipe in the ceiling of the room, and connect it with the outer air, the effect will not be changed; we shall find precisely the same result as with the other arrangements. In place of the water we have the cold air; in place of the spirits of wine we have the warmer and lighter air of the room or saloon, in which the cold air penetrates through the short pipe. If the room should be empty of air, then the air-jet would spring to the ceiling. The greater the difference of the outer and inner temperature, the nearer we approach this case, and the lesser the resist-

ance, the higher in proportion rise the rays over the heads of the inmates. A water-jet always returns to the earth, but it is different with the rising air-jet. The more it comes in contact with the dissolving warmer air, the more quickly it receives the warmer temperature, and the more quickly also vanishes the tendency to descend. The entering fresh air steps into the circular sphere of the existing impure atmosphere; one part of the mixed air escapes through an opening at the ceiling. It is noticed that the greater the difference of temperature between the inner and outer air, the less the inmates gain by the entering fresh air, notwithstanding the greater influence of the cooling process. The higher the saloon is, the farther in height reaches the difference of temperature between the inner and outer air; the higher also you calculate the outer pipe to be, the higher will ascend the rays of fresh air.

From the preceding, it follows, what opinion we may form of another application that has often been made. Basing upon experience, that the air in the upper parts of a heated room is warmer than in the lower, openings have been inserted in the walls close to the floor, to allow the impure air to escape with as little loss of heat as possible. That the lower air of a room is cooler than the upper is certain, but it is equally certain that the outer atmosphere is still more so, and naturally the one enters through the flues inwardly, while the other passes outwardly. This and similar arrangements lead to that great fundamental error. The heat is furnished to the upper parts, whereas the intention

and desire is to use it at the lower. All the impurities of the air wander inseparably with the heat; to restrain and let them escape from the higher strata of the room, has been unsuccessfully attempted. To attain the first point actually, the second is gained, and to attain the latter you infringe on the other. The Doctor says, in a large saloon in Frankfort, a large flue was constructed, with an opening of 5 or 6 feet from the ceiling. Through this flue it was intended the warm and impure air should escape to the outer atmosphere; but the very reverse movement took place, and the cold air rushed into the saloon with such vehemence that the draft had to be stopped immediately. In the Hospital La Riboisière at Paris, the cold air, with the same arrangements, poured into one of the wards, notwithstanding the fresh air was, in great quantity, forced in by a machine. Now let us be clear on these proceedings. If we fill a glass with water, and fill a small pipe with quicksilver, and expect that the water will raise the quicksilver, and then the quicksilver rise of itself, everybody would at once wonder at such a demand; in one case the quicksilver and in the other the heavy air descends towards the bottom, and the water pressed upwards will overflow in the same manner as the lighter air is carried higher in the saloon. Should it be desired, however, to let the air escape through the flue under the ceiling, then it would be necessary to heat this flue still higher than the temperature of the hall. But what would be the result if a flue was to be extended inside the wall to the

floor and heated as it is often done? It is evident that the air rising from the stove, and with it its impurities, descends again and repeatedly, to reach the opening of the flue, and the impurities, or at least a part of them, will again enter through the lungs. There appears now, from the former mentioned case in which the cold air descends to the bottom, and from the one preceding, in which, under similar circumstances, the flow or current is upwards, to be a contradiction in itself. This, however, is only apparently so. If the flue with an outlet 5 or 6 feet below the ceiling of the saloon had been extended to the floor, then the air, by sufficient difference of temperature, would have been equally vehement in rising, but would not descend. In the first case, the descending air follows the law of weight, the same as dropping water; liquid bodies spread all over the bottom and press the extended aerial masses higher. In the second case the air follows likewise the law of weight; it cannot spread apart at the bottom of the flue; it must, by the assistance of the pressure of its additional weight, force the lighter columns of air higher. But this is not the warmer air of the saloon, it is the former descending cold air; it is, however, now concentrated from the former field of action, and the whole pressure acts upon the transverse section of the ascending flues. If the cold air had, for example, covered the whole extent of the saloon floor, 1,000 square feet, one foot high, the adjoining warm air would have been forced up one foot higher also; and if the height of the saloon had not exceeded

ten feet, 10,000 cubic feet of air would have been forced upward one foot. And notwithstanding the transverse section of the perpendicular ascending flue should contain only one square foot, 10,000 cubic feet of air would have been raised one foot in the same time. The laws of nature are infallible; if parts of a mass can move without obstruction, they certainly will regulate themselves according to their weight; the heaviest will seek the lowest, and the lighter by degrees higher positions. Resting upon this law, we are accustomed to see the ascending air from the stove. This is really the case, provided this law has its fair field to operate upon; if not it will fail. The Doctor gives here an example of a Foundling Asylum. The building is two stories in height, and to supply fresh air in the second story wards a hexagon tower was constructed over the roof, from which four horizontal air channels or flues were placed in connection with the tower, and extended under the roof, with an outlet very ingeniously arranged to receive the outer atmosphere. With those flues large canals were connected with the basement, and from them branch canals led the air to the first and second stories to supply circular cast-iron stoves surrounded with chambers to receive the cold air for heating purposes, similar to our furnace arrangements. The most particular examination has given the following results: Nearly one-half of the movements proved unfavorable; one-sixth part entirely contrary to that required. The difficulty, it is stated, gener-

ally took place at night, whenever a brisk wind arose from any direction. The very reverse movement to that required was so strong, that the wards often became very cold, and in the flues the temperature of 30° was noticed. Now let us place this arrangement before us on a smaller scale, which may easily be done. Two perpendicular upright stove pipes communicate and connect at the lower ends by a short horizontal pipe. In this last named pipe hot coals are placed, so that the nearest adjoining upright pipe is heated; and let us call the heated pipe the hot, and the other the cold. A lively cold air stream will enter the latter, and an equally lively warm one will escape from the first. By blowing inwardly into the hot pipe the flow will be reversed in the one inwardly, and outwardly from the other. If the blowing is stopped, a moment's pause will take place, and then the flow will return to its original course. By making the cold air pipe smaller than the hot, then the reverse movement is less likely to take place; the greater the difference of the longitudinal section, even should the cold air pipe be extended to twice or three times the length of the hot, if you blow into the latter a reversed movement will quickly follow, the more so the longer the cold air pipe is; the moment we stop blowing, this flow will with less facility return, and will with more energy persist the longer in it the longer the pipe is. Should we make the cold pipe shorter than the hot, or insert an opening at the bottom of it, the return of the proper movement would take place. It is also easily

comprehended that the return may be gained by blowing into the cold pipe, and it is also easy to give an account of the proceeding. The air expands with each degree of heat 0.00366 of its volume. If heated to 100°, then its volume will increase about one-third more than in its former state. If the two pipes contained an equal volume of air, then they must have an equal height; and if the one is heated to 100°, then the one-third of its air is naturally warmer than the whole volume of the other; consequently the latter is pressed out, the colder air enters the hot air pipe, becomes equally warm, and meets with the same fate as the former air that was pressed out. If we blow into the hot air pipe, then the heat is carried from that pipe to the horizontal piece, and to the cold air pipe, and as a mixture takes place, it is plain that in the cold pipe the heat cannot be as great as in the hot, notwithstanding the flow of hot air; the return is easily possible, particularly if the cold pipe is smaller. Should the latter be double the length, then it will contain two volumes of air with a heat of 100° with $\frac{2}{3}$ loss, and the loss of heat in the short piece proves itself insignificant. It follows, now, that the upper volume of air in the short heated pipe will use its pressure, the outer the same as the inner; consequently two volumes press against $1\frac{1}{3}$ volume. A voluntary turning is not possible to take place. If we open the cold air pipe near the bottom, or shorten it, then the cold air will flow in, the warm air column will be less, and an inversion will take place. The more easily the pipes can be heated, the

better conductors of air they will be, and the more discriminating will easily connect the phenomena with the observation. The shorter piece may play a very important part. The longer it is, the more difficult will be the return. There is not only a restraint by the admissibility of heat, but also by the friction affecting the inner passing flow of air. By canals or sewers below the streets in which the draft of air is under the same influence of the laws demonstrated, this vertical pipe is to be compared with the sewer itself; if very long or extensive, this influence is great. It is not necessary to mention again the case referred to, that of supplying the stoves in the Hospital wards with cold air. What we gain by blowing inwardly can in the other case be effected in various ways, sometimes under favorable circumstances by closing a door. Whenever a strong wind blew into the tower, and consequently into the wards, a reverse shock towards the tower had to follow, similar to the effect of a strong wind upon an inward folding window partly open. With a great heat in the stoves, the return movement naturally took place, and it would have occurred much oftener had the tower been more elevated above the level of the stoves, or the warm air columns supposed to be extended to the ceiling of the saloon. This example proves that the ventilation in the wards of the first story was worse than in the second. The flues or canals referred to in the Hospital, which connected with the two stories and communicated together, would naturally have caused an over-

flow of bad air from one story to the other. The flues from the basement to the ceiling of the second story were larger than those to the first; it follows, therefore, that the flow of air from the first to the second story was more easy than to a reverse movement. The latter movement could only be produced by the heat in the first story being strong, and in the second much milder. It is equally as easy to demonstrate that the northern half of the building is more calculated to assist the functionary movement than the exposure of the southern half a whole day to the sun, as that the whole arrangement proved less satisfactory in the hottest part of the day. We see, therefore, from the aforesaid, that the whole error of the arrangement consists in this, that the cold air has been conducted from the highest point with much cost, whereas it should have been drawn from a deep place, and with less cost. The mistake could have been remedied in a simple way, viz., by shutting up the upper arrangement, and by constructing a cold air flue from the basement descending towards the garden, where the flow would have been inwardly at all times, and the warm air would never have suffered any loss. The idea to lead the fresh air upwards from a hot stove, as was the case in the Hospital, appears on first sight impractical, but with a closer inspection it is found otherwise. By the former example before mentioned it is explained how the cold air is driven upwards in the warm saloon, and it follows hence that we should take notice practically of the ascending

rays. The heated air masses near the stove are the hottest in the whole saloon, and even without the outer pressure the upward flow, on account of its higher temperature, will rise to the highest points of the saloon. But the greater the difference of temperature between the inner and outer air, the more energetical will be the ascending movement. If there is a number of openings, as there should be, placed at the highest points for escape, then it is clear that the newly entered good air escapes without any benefit to the inmates whatsoever. The impurities exhaled by human bodies with less temperature will rise more slowly and less high, and only part of them will be forcibly carried away with the ascending draft. What can be expected to be retained in the saloon? A proportionate small part only of the direct supply of good, and a very large part of impure air. The calculated mixture and amalgamation will be only in a small degree. This evil, nevertheless, will remain the same, no matter whether the openings for escape are there or not. The healthy air will in this case escape through occasional accidental openings, particularly in the higher strata.

It is hardly necessary to state that the air ventilation finds here its proper place also, and that it is impossible for screens, no matter how they are made, to prevent the evil, and we may base on this so evil a circumstance, the cause that the ventilation through warmth has furnished such bad results, while through a mechanical action of force a greater agitation, and consequently a general mixture, takes place.

"But it is likewise true that the difficulties of the one and the other method are attached to each, though in a different degree. In all arrangements in which the hot air is introduced immediately under the ceiling, and the impure colder air, as mentioned before, escapes through heated channels or flues with considerable expense, the great difficulties are then partially overcome, but others before explained remain. I will here mention another characteristic error, which is seldom noticed. It will perhaps set aside any doubts that may still exist. A large escape-flue is constructed above the ceiling, to allow of an escape of impure air. A strong heat is introduced in the upper part of the flue, for the purpose of gaining a strong draft. Now let us return to the plain pipe, and place hot coals, not on its bottom, but on a wire-net arranged so that it may be raised and lowered in the hot air pipe, and then hold a slip of paper over the cold; you will perceive that the flow of air becomes weaker the higher the wire net is raised, and on the contrary that the deeper it is placed, the quicker will be the flow; a result which is easily explained. If the wire net or the warming spring is placed in the middle of the hot pipe, the air volume below the middle part of the hot pipe will be of the same temperature as that below the middle of the other hot pipe. Hence it follows that the two air volumes will hold their balance, and the difference in their weight above the middle, would be equally as great as if the connecting pipe were placed at the same place. The higher the warming spring is

placed, the shorter the communicating pipes are, the less will be the difference in weight, and the less the draft, but larger the expense of the fire material. The aforesaid facts prove how easy it is to penetrate any system of ventilation, if we only fall back upon one or the other simple experiment, by placing stove pipes together in form of communicating pipes. It cannot therefore be difficult to follow every new case that may arise."

HEATING AND VENTILATION OF THE ANCIENTS.

"Many will hesitate to admit that the ancients were ever acquainted with the principles of economical and rational process of heating, and to do justice to the necessity of an effectual ventilation. This assumption will not alone be justified by their knowledge of science, but also owing to their mild climate; large meeting-houses, or public halls, to accommodate thousands of people closely huddled together, were less in demand than at the present time by our social dispositions and climatical demands. Dr. Berger, however, in his work, states that it is very interesting to prove that the ancients in their simple and serene sense of nature actually did heat and ventilate better than we do at the present day, and adds, that it will be absolutely necessary, if we intend to arrive at some perfection in this particular, to fall back on the principles by them introduced. If we intend to make ourselves better acquainted with their arrange-

ments, we must take a different course to that we pursue with our present system. We must, in the first place, become acquainted with the remains which have been left to us by time and events, and with the assistance of the ancient authors, however incomplete their works, the whole will have to be newly constructed. We are bound to inquire first into the designation of the restored arrangements, and after all the previous labor, it is proper for us to enter upon the test to prove the actions which have solely occupied our labor by the newer arrangements. But the proof cannot be determined there as here in the same manner. We cannot by direct experiments prove how much fire material was requisite to produce certain heat at one of those former buildings, or how much the impurities of the air were affected by exhalation and evaporation, and how much time it required to dispense with them in the former arrangement, etc. To do this, the former arrangements have to be in perfect working order. We have to follow different ways; we have to learn from our own and by other experiments the principles most depending upon them, and then we have to ask how far the principles have been employed by the ancients or not. The comparison between the old and new methods will then determine itself. The remains which will serve as a guide may be traced nearly entirely from the Roman baths. They are often found, and in great numbers, not alone in the warmer parts of Italy, where the heating of the private houses is of no consequence, but likewise

in northern climates, particularly in Germany and France. The baths in Pompeii and Herculaneum are mostly in their original state. There are also remains in Rome and in the neighborhood, Serofano, etc. In general they all exhibit the same arrangement of a peculiar heating method, but still there are in several cases various differences, and those very differences will, no doubt, by close investigation, help to raise to our conception the acuteness of penetration the ancients possessed in such a high degree. No doubt the easiest way to arrive at a most correct and clear understanding of their arrangements, will be by explaining a number of examples. We will commence with the winter residence, the villa Tusculana, situated on a hill side near Herculaneum, a description of which, Winkelman introduces with these words: 'The wealthier classes of the Romans were better provided against cold than we are. Their stoves heated the room without molesting the heads of the inmates.' The building is low; underneath the earth is a room of the same dimensions as the room which is located immediately above it, about two feet in height. The lower space or room is named the Hypocaustum. In the last named room are small pillars built of bricks, without mortar, only walled up with clay, the better to withstand the heat. Upon those pillars bricks are laid, and upon them rests the suspended floor. Heating floor called suspensuræ caldarium (Balineæ pensiles). The floor is laid with coarse mosaic, the walls of the upper rooms are cov-

ered with different colored marble slabs. In this floor are square flues walled in, communicating with the Hypocaustum. These flues are built in the surrounding walls, and extend to the upper or second story room, where the heat escaped through lions' heads made of terra cotta, and regulated by a plug or stopper. A small passage leads into the Hypocaustum. On the other end of the passage is the heating stove (Hypocausis præfernium,) from which the heat enters through the passage into the Hypocaustum, and from thence through the flues, so that the floor became heated first, and afterwards the walls. The floor of the second story, probably constructed similarly to the first, but perhaps of less thickness, was heated by the heat of the room below. Such a general and equal diffusion of heat was not accidental, but calculated. Therefore Seneca remarks, the lowest and highest part receives its heat equally. This mode of heating private dwellings is also used for heating baths, private as well as public baths, and the most important part of them seems to be the hot room or Caldarium. The bath of Buxweiler in Alsace had a somewhat different arrangement to the above. The pillars or piers supporting the floor were less in number, but the heating flues were not close together as in the former; on the contrary, a space was left between them, which had no openings, except in the Hypocausis, and an outlet on the end communicating with the open air. Immediately after the suspended floor became warm; the smoke entered the flues and escaped through the

upper outlets. The entrance door was placed immediately over the fire room, also at a place on the floor where the temperature was the highest, so that the draft of the air through the opening of the door, was at once mixed to an equal temperature. But the flues were not always conductors of heat. The public baths at Pompeii, for instance, had double walls constructed of burnt tiles, set up endways with an open space of four inches secured with holdfasts, so that the whole room was actually surrounded with a single air volume. Is it not plain, that this arrangement proves most strikingly that the equal temperature, particularly at the floor, was attained in a most excellent manner, but it is noticed, there is no preparation made for ventilation? But still the arrangement of the Lichtenberger bath in Germany, proves that they recognized the necessity of introducing fresh air then in the Tepidarium. The mild heated bathing room is entered by a canal to supply fresh air, and we shall also find that there was care even taken for the escape of impure and heated air to a sufficient extent. Both were particularly requisite in the Caldarium, the heated room. It is easily comprehended that in this room fresh air had to be introduced most cautiously. A great flow of quite cold air, or of air alrogether of low temperature, would have acted upon the perspiring multitude not alone uncomfortably, but very dangerously. The entering air had first to be cleared of its peculiar and offensive qualities. It appears this purpose has been gained in a most judicious manner, by an arrangement

which is illustrated in a picture found in the baths of Titus. This picture exhibits next to the right two fires under two boilers, calculated for water heat. The Hypocaustum is divided by three large fire canals, placed on a level, calculated to spread under the entire suspended floor. Between the ceiling of the single division of the Hypocaustum and the suspended floor three more small fires are placed. Those small fire rooms are perhaps nothing more than a continuation of the three first named larger canals, extending to an equal height at the bottom of the larger canals for firing purpose ; the fuel is seen burning ; and bending over the Hypocaustum, in a right angle around, the flames are noticed horizontally between the ceiling and the suspended floor, in a continued stretch forward. The discharge of the horizontal fire channels may be traced to the heating flues, probably placed in the opposite rear wall, but impossible to be shown in the picture. On the left side of the picture, openings are seen at some distance from the floor ; these openings which incline to the ceiling of the Hypocaustum, entered the room in a downward flow. In the ceiling an outlet was prepared, by which the hot air had a chance to escape. This arrangement was found in a bath house at Serofano, not far from Rome, and it seems to be general ; involuntarily those reflections call to recollection a former quarrel, which was carried on in the past age, with great expenditure of sagacity and loss of time over the question, whether the Romans had actually chimney stacks or not. This

quarrel is somewhat amusing. One party was determined that the smoke should escape through the window openings in the walls, through the roof etc., and the other was determined that it should escape through the chimney. At the same time both parties were a unit that the smoke did neither pass through the window nor other wall openings, nor through the chimney flues, but through the heating flues. However, nobody will lessen the merit this chimney quarrel deserves, and it proves how this advanced heating method met with a general application wherever heat was requisite for a continued purpose, and by this method only could a perfect result be expected."

COMPARISON OF THE OLD AND MODERN METHODS.

"The main difference between the two methods can be explained very clearly by simple examples. Take, for instance, a stove composed of terra cotta tiles, and place a warming spring, a gas or spirit flame, and as near the bottom as possible, and near to the side wall of the same. Then examine the temperature, and you will find that the same increases from the bottom upwards very rapidly, and that the process of heating the bottom and walls is slow, and much slower at the bottom. You may feel that the air enters at the lower openings very rapidly, and that this same air escapes very strongly heated. If the warming spring or gas light is withdrawn, the former

phenomenon diminishes as rapidly as it first appeared. By placing a warming spring below the bottom of the stove, then the walls will be heated much more than before. The bottom receives naturally, not a lower but a higher temperature than the other. In the inner space the temperature is higher below than above, but in a short time the change may be the reverse; the difference, however, between the upper part and the lower is small. The air which escapes from the chimney flue is by no means as hot, and vehement in its movement; it is on the contrary slow, constant, and less heated. As soon as the warming spring is removed, then the difference in warmth between the upper and lower part returns to its former proportions. The constant air draft continues for a considerable time, and by degrees works forward. The floor and walls have inhaled the warming spring, and changed to warming springs themselves, but with a nature not allowing the heat to escape rashly, and spouting, but sparingly, and in sufficient quantity. The first of the two experiments represents the heating method of the newer times; it furnishes the heat especially and rashly upwards; that means, to a place where it is not wanted. The last experiment represents the method of the Romans. This method furnishes the heat especially and quickly into the lower parts of the room to be heated, and precisely to the place where wanted. Our methods drive a considerable part of the heat out of the chimney flue, without any service to the chief object. The Romans dispense with the

smoke, but take the advantage of it, and apply its heat for heating purposes; the smoke rises between the space of a thick outer wall and thin inner wall. But the room is heated, not alone by the smoke, but also through the heated air of the Hypocaustum; each operates in its individual capacity, and still there is heat enough, so as not to disturb the rising power of the smoke. Our methods confine the principal bearer; the other part of heat, the movable air; by this means it will become as movable as the bearer, and with these enters rashly to the upper part of the rooms, the inmates below receive the rest, which is impossible to place above.

"The Romans consequently retain this part in the lower strata, not trusting to the movable air, but to the compactness of the clay. The air is only an intermeddler, the heat is carried to the ceiling, but only to the ceiling of the Hypocaustum. The heat is here concentrated and supplies the air of the room continually, and in such quantity as is requisite for the inmates, not more; and not a particle can escape which has not been used. Our methods are calculated to supply the floor, with bad warming conductors. The Romans construct the floors also not with the very best conductors of heat, otherwise they would have suffered with too much heat, but nevertheless sufficiently good without waste of fuel.

"It is a fact, our methods molest the head with unhealthy heat, and leave the feet cold. The ancient method warms the feet and leaves the head free.

"Our methods conduct the heat in one air stream of small horizontal extent, concentrated to the upper part of the room to be heated. Close to the air current the occupant finds himself too warm, and the more remote he keeps from it the more he feels cold, too cold! all in one and the same room. The ancients knew nothing of a hot air current; every where in the occupied room, there was an equal and a continued flow of mild warm air. It was not possible to find one part of the room too hot and the other too cold. Should part of the floor near the heating apparatus prove too hot, then it follows that the colder air will flow more rapidly. The upper rooms of the ancients prove to be as comfortable as the lower; the upper parts of our theatres and concert rooms prove unsupportable for any length of time, even with a mechanical ventilation.

"The air which rises in the flues of the ancient arrangement, will furnish heat, and by this process will prevent the air rising in the room from returning to the floor. Our walls and windows are cold, and lead the impure and refrigerant air repeatedly to the lungs of the inmates.

"The temperature of the floor and the walls required with the ancients not to be more than the temperature requisite for the room, and it necessarily should be so. The difference of temperature between the outer air and the air in the room could never be so great as the rising air near a stove, or from an air-heating apparatus. So whenever the outer air was introduced, no matter in whatever way, owing to the difference in

temperature, the inward current of air could never enter violently. On the contrary, the colder air was forced to descend gently to the floor, receive its warmth and then rise again, but not descend a second time, not meeting with any cooling process on the walls; and through the outlet flue the warmer and the mixed impurities of the air escape, without being inhaled continually. All our new systems of ventilation either produced by mechanical power or heat, lead, with few exceptions, a strong hot and cold air current into the air to be purified, and create a most stirring motion, and cause a most complete mixture. Those with heat connected systems are calculated for the greatest difference in temperature, and carry the supplying good air, or so much of it as is not mixed, quickly through the outlet flues. The ancients, however, were contented with a much less difference in temperature, and lessened the same accordingly. Mixture was not the object, but an equal rising of consumed air current through corresponding differences of temperature. Not a single violent air current is introduced; a great number of gentle small rays are spread calmly upon the floor, and lift the consumed air equally and continually upwards, never to return. A mixture, as formed in the other case, is impossible. A colossal air draft of 60 metres for each person is not necessary. The limit is gained by a minimum. To guard against the mechanical action of the strong air rays brought in, and also against the action of the higher and lower temperature, screens of various forms are introduced,

which never answer the purpose thoroughly; besides, a quantity of air rays introduced presents another disadvantage. It takes too long a time to disseminate, and it follows that the current of air in a perfectly clear condition, acts only in a confined and local way, and never in a general way. The ancients introduce the warmer air in fine rays on all sides, and so remove all objections. But this gentle withdrawal in this gradual manner, has a great advantage over our treatment; and to illustrate it more clearly, some well known facts are necessary to be here introduced. Whenever the door of a heated room is opened, then the cold air enters at the bottom of the opening, but escapes at the upper part; a light will clearly prove this, if applied to the opening. Whenever a window is opened, the same movement is noticed, no matter how large or small the windows may be, or no matter in what position the window is placed, at the lower or at the upper part of the heated room. The cause of this phenomenon is well known: the cold air forces itself in at the lower part, and the warmer air must escape at the upper part, and the consequence is that the exit of air stops at the window at the time an opening is placed above the window. The well-known method of ventilation, in which a hollow cylinder, divided longitudinally into two parts, and placed in the wall or ceiling, rests upon the same principle. Now we can form a clear view of what is called a voluntary and natural ventilation. The numerous pores in the materials are so many ducts for the inlet and outlet of air, and the change of air

through those pores takes place as indicated. By due reflection, it is easily seen that the ventilation of the ancients conforms to the imitation of the natural ventilation. When the cooler air enters from a lower opening of a flue into a heated room, the warm and supplanted air rises in the next higher opening of the heated flues, an occurrence which repeats itself throughout the room, below and above and on all sides. So the impure air travels only one way to the outlet, the impure air is not lifted from the floor to the ceiling, every sheet of air requires only to rise gradually. It is clear that through this process the desired result is most surely gained. It is otherwise with our newer method, where the air generally enters at the lower part and escapes at the upper part, equally so as the accumulating impurities move through the whole height of the saloon, and where the heated air forms its exit through the opening arranged as above, whereas the lower impurities, not ascending so high, remain behind. The dwelling rooms and bath rooms of the ancients were at an average not so high as ours, and it was not necessary they should be. By our methods it is important that in the mixture of pure and impure air, the pure air should be in a sufficient healthy surplus.

"The larger and higher the rooms are, the better. The ancients required no such elevation; on the contrary, by the process of lifting the impure air gradually, the interest of economy was applied, to keep the rooms low; every extension of height requisite for hab-

itable rooms is actually an extravagant consumption, requiring more heat. The heating and ventilation conception, however, to which we have accustomed ourselves, will naturally restrain us; but as soon as we acknowledge the advantage of the arrangements of the ancients, with good air equally distributed, then we shall require less room for the accumulation of good air. The finest mosaic work and ornaments for floors and walls of the ancient works, are known. They form a contrast to the newer works, and the contrast of the practice of using in the one case good and in the other bad warming conductors, is in favor of the ancients, with a corresponding claim to art also. It is hardly possible to suppose that there could be any opposition to the hope that theory only has been preached, without experience. Experience is in advance of theory at least two thousand years, and is introduced by economical, practical and judicious men, by men every way trustworthy. The main object here is only the first trial in a time of flourishing science, to form a comparison of the results with those of newer methods of heating in connection with ventilation. Then when this first trial has been made, I think it will be unnecessary to say anything more in its favor; it will speak for itself. All that is left to be done is this, to perfect this method by still more experience and through science.

"Then the combat between ventilation through heat or through mechanical power, will subside in itself. We have, in this system, economical heating connected

with the natural ventilation. Hitherto the trifling effects of the natural and voluntary ventilation, through the pores of the walls and other accidental openings, it was taken for granted could be assisted in two different ways, and so the natural ventilation may be elevated to its greatest perfection, and if not found sufficient in all cases, then the mechanical power may assist, by forcing the pure air perhaps through the same air flues, through which the voluntary air may enter. There is no comparison more between the two methods. It will not be questionable, the one or the other, but one alone, or in connection with the other—a question which will easily be settled by a strict inquiry into the condition of the air in single rooms."

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